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PROTOPLASM AND THE CELL DOCTRINE.

ANNUAL ADDRESS OF THE PRESIDENT, CHARLES F. COX, M. A.

(*Delivered January 3d*, 1890.)

Truth, like the ocean, tends to a general level ; but its surface is always ruffled by winds of speculation. All philosophy is either above or below the normal line of ascertained fact. A lack of knowledge keeps it in the trough of the sea ; a superfluity of imagination carries it upward on the crest of the wave. In any case it holds a restless course, tossed hither and thither by the shifting breeze of opinion.

Every hypothesis starts from a point much lower than the actual truth-level, is pushed by the enthusiasm of its advocates far beyond the limit of rigid induction, and then, after many gradually weakening oscillations, is finally brought down to a state of nearly stable equilibrium by the force of logical gravitation.

Such has been, in part at least, the history of the hypothesis which has come to be known as the protoplasmic theory of life. The stream of doctrine which has resulted in this theory had its origin a little over fifty years ago, in a reaction from the then prevailing belief in a vital principle, or spiritual essence, which was not evolved by the parts or organs, but which entered into and took possession of the organism as a whole and caused it to live.

It would seem as if protoplasm must have come under the notice of the first serious worker with the microscope, although not

known by this name nor recognized for what it was afterwards seen to be. As early as 1755 Rosenhof described pretty clearly and correctly the curious phenomena of vitality as manifested in the movements of the "proteus animalcule" and seventeen years later Corti published his observations on the rotation in the cells of Chara. The similar process in Vallisneria was made known by Meyen in 1827, and in 1831 Robert Brown was overawing Charles Darwin with that "little secret," which proved to be his newly discovered cyclosis in the filaments of Tradescantia.

About the time that Corti was studying the formative material in Chara, Wolff, according to Professor Huxley, was trying to demonstrate, with reference to the higher animals, that "every organ is composed, at first, of a mass of clear, viscous, nutritive fluid, which possesses no organization of any kind, but is, at most, composed of globules."[1]

In 1835 Dujardin put forth his celebrated memoirs on the Foraminifera, in which he called attention to the "*substance animale primaire*," of which they are composed, which he described as "une sorte de mucus doué du mouvement spontané et de la contractilité," and to which he gave the name "*sarcode*."

But according to Doctor Drysdale, Doctor Fletcher, of Edinburgh, is entitled to the credit of first having given the *coup de grâce* to "the old hypothesis of a vital spirit, or essence, or principle as the cause of life," and of having framed a new theory "of the anatomical nature of the living matter which anticipates, in a remarkable manner, the discovery of the protoplasmic theory of life." In support of this claim we are referred to Doctor Fletcher's "Rudiments of Physiology," published in 1835, in which it was argued (1.) "that there can be no central vital influence communicable to the parts and dominating them, for the vitality of each must be inherent in itself, and, as a property of the material compound, cannot be transferred to the smallest distance; each part, organ, and even cell, therefore, possesses a quasi-independent life, and they are all bound together to form an individual merely by the ties of a central nervous system and common circulation, or some similar

[1] "The Cell Theory." By Thomas H. Huxley. Brit. and For. Med. and Chir. Review, October, 1853.

means when these are not present;" and (2.) "that the property of vitality does not reside equally in the various organic structures requiring such different physical properties, but is restricted solely to a universally-diffused, pulpy, structureless matter, similar to that of the ganglionic nerves and to the gray matter of the cerebro-spinal nervous system."[2]

As Doctor Drysdale remarks, "the progress of physiological knowledge from the time of Fletcher may be said to be bound up in the history of the cellular theory, which may be considered practically to have begun in 1838." But, as stated by Doctor Tyson, "it is evident that for some time prior to the year 1838, the cell had come to be quite universally recognized as a constantly recurring element in vegetable and animal tissues, though as yet little importance had been attached to it as an element of organization, nor had its character been clearly determined."[3]

It is to be noted, however, that nearly all the earlier observers dealt exclusively either with animal or with vegetable cells. It is probable that Schwann was the first to bring both animal and vegetable worlds under a general theory of cell-formation and growth; although Oken, as far back as 1808, had declared that "animals and plants are throughout nothing else than manifoldly divided or repeating vesicles." Oken, however, appears to have been engaged wholly with the morphological resemblances between the elementary parts of animals and plants, and, as Schwann himself remarks, "nothing resulted from such comparisons, because they were mere similarities in figure between structures which present the greatest variety of forms."

In 1837 Schleiden had made his discoveries as to the process of origination and development in vegetable cells and had, previous to publication, laid his conclusions before Schwann. In enumerating the substances composing the cell-contents Schleiden referred to a semi-granular substance occurring in irregular forms, having no internal structure, which was colored brown by tincture of iodine, and which he proposed to call mucus. He however distinguished another, still simpler mat-

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[2] "The Protoplasmic Theory of Life." By John Drysdale, M. D., F. R. M. S. London, 1874.

[3] "The Cell Doctrine: Its History and Present State." By James Tyson, M. D. Philadelphia; 2d. Edn., 1878.

ter, apparently a portion of the former, and in this respect seems to have anticipated some of the very latest developments of the protoplasm theory, of which I shall speak by-and-by, though his distinction of parts in the mucus came to be entirely overlooked when the whole granular mass afterwards received the name of protoplasm. He taught that "the youngest structures are composed of another distinct, perfectly transparent substance, which presents an homogeneous, colourless mass when subjected to pressure;" which, after pressure, "appears as colourless as before, and is so completely transparent as to be altogether invisible when not surrounded by coloured or opaque bodies." This he named vegetable gelatine. "It is this gelatine," he says, "which is ultimately converted by new chemical changes into the actual cellular membrane, or structures which consist of it in a thickened state, and into the material of vegetable fibre."[4] Here we have at least the root of the doctrine of germinal matter and formed material.

Now, taking Schleiden's observations for his starting-point, Schwann made an immense advance upon them, by using them as a key to the mysteries of animal development, and by deducing from them a new and far-reaching generalization. The task he took upon himself was to prove that "one common principle of development forms the basis for every separate elementary particle of all organized bodies, just as all crystals, notwithstanding the diversity of their figures, are formed according to similar laws." He sums up the matter by saying that "in the fundamental phenomena attending the exertion of productive power in organic nature a structureless substance is present in the first instance, either around or in the interior of cells already existing, and cells are formed in it in accordance with certain laws, which cells become developed in various ways into the elementary parts of organisms."[5]

From this time on, for ten or twelve years, the history of the cell doctrine is little more than a record of shifting views as to the relative importance of the cell-wall and the cell-contents. In the contest, however, the enclosing membrane was constantly

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[4] "Contributions to Phytogenesis." By M. J. Schleiden. Sydenham Soc., 1847.

[5] "Microscopical Researches into the Accordance in the Structure and Growth of Animals and Plants." By Dr. Thomas Schwann. Translated by Hy. Smith. London, 1847.

losing and the enclosed plastic matter was constantly gaining in physiological significance. Even the nucleus was losing its essential character, so that when Cohn made known his observations on Protococcus Pluvialis,[6] the scientific world was ready to believe that the vegetative changes occurring in the cell-contents of this organism were brought about without the direct agency, if not actually in the absence, of any nucleus, whatever.

In 1844 Hugo von Mohl first applied the name protoplasm to the "opaque, viscid fluid of a white colour having granules intermingled in it," which he found filling the cells of plants.[7]

But now, in 1850, Cohn widened the boundaries of Schwann's great generalization by showing that there is not only a morphological similarity between the constituent cells of animals and those of plants but that there is a physiological analogy, if not also a chemical identity, between vegetable protoplasm and animal sarcode. He expressed the opinion that this common substance "must be regarded as the prime seat of almost all vital activity."

Up to this point the cell had been the only recognized vital unit, and the conception of an enclosing wall, semi-fluid contents, and a nucleus, as the essential and always present constituents, had been pretty generally insisted upon, although Cohn had partly disposed of the nucleus. *Omnis cellula e cellulâ* was still the orthodox tenet, when Leydig attempted to relegate the cell-wall to an incidental position as a mere hardened surface of the cell-substance, while retaining the nucleus as an indispensable centre of vitality, thus reducing the cell to "*protoplasm* inclosing a nucleus."[8]

In 1858 Professor Virchow abandoned the wall as an essential part of the cell, and gave in his adherence to the view that "a *nucleus* surrounded by a molecular blastema was sufficient to constitute a cell."[9]

But Doctor Tyson is disposed to award to Max Schultze "the credit of having fully overturned the vesicular idea of cells." Schultze, he says, in 1861, "insisted upon some modi-

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[6] Ray Society. 1853.

[7] "Principles of the Anatomy and Physiology of the Vegetable Cell." Translated by A. Henfrey. London, 1852.

[8] "Handbuch der Histologie." 1856.

[9] "Cellular Pathology." Translated by F. Chance. Philadelphia, 1863.

fication of prevailing views respecting the relation of cell-wall to cell-contents, and contended for a higher position for that part of the cell corresponding to the protoplasm of von Mohl, * * * * and showed how a careful study of the phenomena presented by the pseudopodia, extended by the various Rhizopods, might aid in clearing up the life of the elements of the cell. He also defined the cell as protoplasm surrounding a nucleus."[10]

Now the cell-wall ceases to occupy attention. Henceforth the contention is over the nucleus. Brücke attacked it in this same year and undertook to show that it has a very doubtful existence in the realm of cryptogamic botany, provided, as he naively remarks, we "do not start out with the belief that the nucleus is there even though we do not see it." The discovery of non-nucleated protozoa, soon after extended the same skepticism to the animal kingdom; and so the way was prepared for Beale's theory, which was then announced. Its basis was laid in some preliminary publications in 1860; but it was more formally expounded in 1861, in a series of lectures delivered at the Royal College of Physicians. Still later, it was further elaborated in ten lectures given at King's College.[11]

The substance of his theory, as set forth in these lectures, is that every living being, from the simplest to the highest and most complex, is composed partly of a semi-fluid, granular material and partly of more solid tissues; that the tissues are formed from the granular material; that the granular material is always within, the formed material on the outside of an elementary part; that the granular material alone is concerned in the operations of growth, nutrition, and development,—alone possess the power of selecting pabulum; that pabulum is worn-out tissue; and that therefore there are but two kinds of substances in every organism, namely, germinal matter and formed material:—the former always alive, the latter always dead.

He tells us that "the germinal matter which is formed in the nerves or muscles of any of the higher animals cannot be distinguished from the germinal matter in the tissues of the leaf of a plant, or from that which exists in the particles of the lowest

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[10] "The Cell Doctrine." P. 80.

[11] "On the Structure and Growth of the Tissues, and on Life." London, 1865.

fungus," that germinal matter is met with in varying proportions in all living tissues, but that it is most abundant in those most actively growing, and that, in the earliest period of their existence, tissues are entirely composed of it. He claims to have shown "that every particle of matter exhibiting vital phenomena is derived, not from the formed material, but from pre-existing living or germinal matter, which exhibited similar phenomena, and so from the first creation." This living matter is always colourless, always contains much water, and is structureless and formless, although Doctor Beale says that it "consists of particles, which, when free, invariably become spherical," and that these spherules "are composed of spherules ad infinitum." Finally, he expresses the belief that, in the living state, "the elements of the matter and the forces associated with them are maintained in some remarkable and exceptional condition which is quite peculiar, to which no parallel whatever can be offered," and which he attributes "to the operation of *Vital Power*."

Doctor Beale's King's College lectures were greatly expanded in later years, and underwent changes of form and of name; but I cannot see that much was really added to the substantial framework of his theory. A considerable weight of controversial matter, was, however, superimposed, and this proved, as might be expected, an element of weakness rather than of strength. But, although his later works did not actually enlarge the scope of his hypothesis, they afforded him opportunity to state more fully his views of some of the less essential details. Thus he was able to elaborate his conception of the wide separation between his two forms of organic substances, and to insist with more emphasis "that between the living state of matter and its non-living state there is an absolute and irreconcilable difference; that, so far from our being able to demonstrate that the non-living passes by gradations into, or gradually assumes the state or condition of the living, the transition is sudden and abrupt; and that matter already in the living state may pass into the non-living condition in the same sudden and complete manner; that while in all living things chemical and physical actions occur, there are other actions, as essential as they are peculiar to life, which, so far from being of this nature, are opposed to, and are capable of overcoming, physical and

chemical attractions;" and, moreover, "that the non-living matter is the seat of the physical and chemical phenomena occurring in living beings, but that the vital actions occur in the living matter only."[12]

But, beside furnishing the occasion for greater particularity in the exposition of his theory of life, Doctor Beale's newer presentation of the general subject opened the way to interesting and somewhat novel ideas concerning death. He accordingly undertook to convince us that "all form, colour, structure, mechanism, observed at a later period in the life-history of living things, result from changes in this primary structureless, colourless material, * * * * which looks like mere jelly, or a little clear gum or syrup;" and that these changes—these transitions from formative to formed—are universally accompanied by a cessation of life. They are the converse of the process by which dead pabulum becomes living protoplasm, and all vital action on one side and all organic form on the other result from the swing of the pendulum to and fro,—the down beat being no less important than the up beat. According to his conception "all bioplasm must die. By its death marvellous things are produced and wonderful acts are performed. Every form in nature,—leaves, flowers, trees, shells; every tissue,—hair, skin, bone, nerve, muscle,—results from the death of bioplasm. * * * * Once dead, bioplasm ceases to be bioplasm and is resolved into other things; but these things that are *formed* cannot be put together again to reform the bioplasm. They may be taken up by new bioplasm, and so converted into living matter; but the bioplasm that existed once can never exist again."

Concerning the origin of bioplasm, Doctor Beale offers no very distinctive belief. He says, however, that "whether one primitive mass of bioplasm was caused to be, in the first creation, or five, or fifty, or whether thousands or millions, rushed simultaneously or successively into being, is open to discussion; but the arguments in favour of the view that a minute mass of structureless bioplasm was the first form of living thing are so overwhelming that they must carry conviction."

A few years before these passages were written, Doctor Beale had first proposed, as an exclusive name for the "living or self-

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[12] "Bioplasm; an Introduction to the Study of Physiology and Medicine." London, 1872.

increasing matter of living beings," this word *bioplasm*, and in support of its application had urged that "now that the word biology has come into common use, it seems desirable to employ the same root in designating the matter which it is the main purpose of biology to investigate "[13] The word *protoplasm* had been associated with too many different substances to suit Doctor Beale's object which was to indicate matter in its most unstable form, before it has become an organ, a structure, a tissue, a cell ;—while it is merely formative but still unformed. The older word, as Doctor Drysdale remarks, had "been used in a loose way and applied to objects which have no title to vitality," and, as the term *germinal matter* had, for some reason, been thought inconvenient, Doctor Beale sought to create a name which should mean simply and solely *living plastic matter*, or, as Huxley afterwards called it, *life-stuff*. But *protoplasm* could not be dispossessed and, though *bioplasm* is probably the better word, the older name descended by inheritance to the new idea, and even Beale himself accepted and used it in his later works.

In fact, there may be very good reason for this supremacy of the original designation if, as Doctor Drysdale asserts, "the living matter of Beale corresponds to the following histological elements of other authors : the viscid nitrogenous substance within the primordial utricle, called by von Mohl, protoplasm ; the primordial utricle itself in Naegeli's sense of that term, viz., the layer of protoplasm next the cell-wall ; the transparent, semi-fluid matter occupying the spaces and intervals between the threads and walls of those spaces formed by the so-called vacuolation of protoplasmic masses ; the greater part of the sarcode of the monera, rhizopoda, and other low organisms ; the white blood-corpuscles, pus-corpuscles, and other naked wandering masses of living matter ; the so-called nucleus of the secreting cells, and of the tissues of the higher animals, and many plant-cells ; the nuclei of the cells of the grey matter of the brain, spinal marrow, and ganglions, and the nuclei of nerve-fibres."

Doctor Beale himself puts the case quite as strongly in his latest work on this general topic, in which he says : "if certain authorities were asked to define exactly the characters of the matter which they called protoplasm, we should have from those

[13] Quart. Jour. Mic. Sci. July, 1870.

authors definitions applying to things essentially different from one another. Hard and soft, solid and liquid, coloured and colourless, opaque and transparent, granular and destitute of granules, structureless and having structure, moving and incapable of movement, active and passive, contractile and non-contractile, growing and incapable of growth, changing and incapable of change, animate and inanimate, alive and dead,—are some of the opposite qualities possessed by different kinds of matter which have nevertheless been called protoplasm."[14]

Notwithstanding the justness of this criticism of the general looseness of other authors, there is some ground for thinking that Doctor Beale has not been entirely clear and consistent in his description and identification of his own germinal matter; for, although he declares that "bioplasm or living matter is always transparent, colourless, and, as far as can be ascertained by examination with the highest powers, *perfectly structureless*," he afterwards speaks of the substance of the amoeba as being "darker and more granular in some places than in others;" he distinctly admits that "the bioplasm of all organisms, and of the tissues and organs of each organism, exhibits precisely the same characters;" and he still later refers to the "component particles" of bioplasm, which he finally distinguishes as bioplasts. The ovum, he tells us, "at an early period of its development is but a naked mass of bioplasm, without any cell-walls, but having a new centre or many new centres (known as germinal spots or nuclei) embedded in it." These germinal spots "are in fact new living centres of growth," and we may perhaps be excused for asking whether the existence of so great differences of function in different parts of the bioplasm of the amoeba, the white blood-corpuscle, the Vallisneria bioplasm, the mucus corpuscle, and the ovum, are not pretty strong indications of structure. The question is therefore whether these things are, after all, composed entirely of bioplasm; for Doctor Drysdale lays down the rule that "the name of bioplasm, given by Beale, or protoplasm (in a restricted sense, as it will probably be ultimately accepted by biologists), as indicating the *ideal* living matter, cannot be given to any substance displaying rigidity in any degree, from the softest gelatinous membrane up

[14] "Protoplasm; or Matter and Life." 1874.

to the hardest teeth-enamel ; nor to anything exhibiting a trace of structure to the finest microscope ; nor to any liquid ; nor to any substance capable of true solution."[15]

It is plain from all that has been said that Beale's theory dispenses with the cell-wall as an essential part of the ultimate physiological unit, and that under his system the nucleus becomes a mere centre of activity :—the spot where vitality bubbles up and overflows to the adjacent protoplasm. The mystery of life is therefore narrowed to a veritable point within a simple habitat ; and, in the words of Doctor Drysdale, the problem which Doctor Beale had undertaken was "to account for all the vital phenomena of a complicated individual of the higher orders by the sole action of this structureless, clear, semi-fluid matter."

But now Professor Huxley takes in hand the broader task which Cohn had begun twenty years earlier, in an endeavor to prove that "there is some one kind of matter which is common to all living beings, and that their endless diversities are bound together by a physical, as well as an ideal, unity." This is the primary thesis of his lecture on "The Physical Basis of Life,"[16] or, as he at first entitled it, "The Bases of Physical Life."[17]

Now Doctor Beale has said that, although all bioplasm possesses certain common characters, "we must admit that in nature there are different kinds of bioplasm indistinguishable by physics and chemistry, but endowed with different powers, flourishing under different circumstances, consuming different kinds of pabulum, growing at a different rate and under very different conditions as regards temperature, moisture, light, and atmosphere, posessing different degrees of resisting power, and dying under very different circumstances, having varying powers of resisting alterations in external conditions." Doctor Beale's bioplasm is therefore an "ideal" living matter, of a generic similarity rather than of a specific identity.

Although the general purpose of Professor Huxley's essay is to show that all protoplasms are one, or that they are mutually convertible into one another, he is obliged, at the outset, to

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[15] "The Protoplasmic Theory of Life." P. 45.

[16] Fortnightly Review. Feby. 1, 1869.

[17] The Scotsman. Nov. 9, 1868.

make an admission somewhat in the line of Doctor Beale's distinction between bioplasms "consuming different kinds of pabulum;" for he is so frank as to say that "notwithstanding all the fundamental resemblances which exist between the powers of the protoplasm in plants and in animals, they present a striking difference * * * * in the fact that plants can manufacture fresh protoplasm out of mineral compounds, whereas animals are obliged to procure it ready made, and hence, in the long run, depend upon plants." While his imaginative eye is able to see a "community of faculty * * * * between the brightly-coloured lichen, which so nearly resembles a mere mineral incrustation of the bare rock on which it grows, and the painter to whom it is instinct with beauty, or the botanist, whom it feeds with knowledge," or to discern a hidden bond connecting "the flower which a girl wears in her hair, and the blood which courses through her youthful veins;" he nevertheless stops to have it "understood that this general uniformity by no means excludes any amount of special modifications of the fundamental substance." Still, in the protoplasm of the microscopic alga or fungus, and that of the leaf-cell or leaf-hair; in the substance of the organless and almost formless moner or amoeba, and that of the ever-changing white blood-corpuscle of a whale or of a man; in the matter of the nucleated epithelial cell, and that of the animal ovum; he beholds "the clay of the potter; which, bake it and paint it as you will, remains clay, separated by artifice and not by nature, from the commonest brick or sun-dried clod." "Thus," he concludes, "it becomes clear that all living powers are cognate, and that all living forms are fundamentally of one character."

Then he goes on to say, "the researches of the chemist have revealed a no less striking uniformity of material composition in living matter. In perfect strictness it is true that chemical investigation can tell us little or nothing, directly, of the composition of living matter, inasmuch as such matter must needs die in the act of analysis." One fact, however, remains out of reach of the refinements of logic which objectors have raised upon this point: "and this is that all the forms of protoplasm which have yet been examined contain the four elements, carbon, hydrogen, oxygen, and nitrogen, in very complex union and that they behave similarly towards several reagents."

As to the bearing of all this upon the cell-doctrine, Professor Huxley gives it as his opinion that "a nucleated mass of protoplasm turns out to be what may be termed the structural unit of the human body. As a matter of fact, the body in its earliest state, is a mere multiple of such units; and, in its perfect condition, it is a multiple of such units variously modified." "But," asks Professor Huxley, "does the formula which expresses the essential structural character of the highest animal cover all the rest, as the statement of its powers and faculties covered that of all others?" And his reply is: "Very nearly. Beast and fowl, reptile and fish, mollusk, worm, and polype, are all composed of structural units of the same character, namely masses of protoplasm with a nucleus. There are sundry very low animals, each of which, structurally, is a mere colourless blood-corpuscle leading an independent life. But at the very bottom of the animal scale even this simplicity becomes simplified, and all the phenomena of life are manifested by a particle of protoplasm without a nucleus."

It ought, however, to be pointed out here, as it was long ago by certain writers, that, notwithstanding the similarity in form between a moner and a white blood corpuscle, the corpuscles of a whale spilled in the sea would not continue their existence as monera, nor would monera injected into the veins of one of the higher animals perform the offices of the blood-corpuscles.

At any rate, it is very evident that Professor Huxley is one of those who have discarded the cell-wall as an essential part of the structural unit, though it is not quite certain that he is ready wholly to relinquish the nucleus. Still, his theory, like Beale's, calls for a formative *matter*, rather than a forming *vesicle*, as the foundation of every living structure, and the cell-wall, when there is any, becomes a result of what then becomes cell-contents:—the latter being cause to the former as effect, just as the test is the product of the enclosed foraminifer, or the shell of the mollusk.

Having settled upon a mere mass of living matter as the structural unit, Professor Huxley inquires "now what is the ultimate fate and what the origin of the matter of life? Is it, as some of the older naturalists supposed, diffused throughout the universe in molecules which are indestructible, and unchangeable in themselves; but, in endless transmigration, unite in

innumerable permutations, into the diversified forms of life we know? Or is the matter of life composed of ordinary matter, differing from it only in the manner in which its atoms are aggregated? Is it built up of ordinary matter, and again resolved into ordinary matter when its work is done?" To these queries Professor Huxley, in the name of modern science, answers, as Doctor Beale would answer, that "under whatever disguise it takes refuge, whether fungus or oak, worm or man, the living protoplasm not only ultimately dies and is resolved into its mineral and lifeless constituents, but is always dying, and, strange as the paradox may sound, could not live unless it died." "All work," he goes on to say, "implies waste, and the work of life results, directly or indirectly, in the waste of protoplasm." But "it is clear that this process of expenditure cannot go on forever," and so the problem is reached: how is the renewal of protoplasm accomplished? Here again Professor Huxley answers as Doctor Beale would answer:—by the appropriation and assimilation of pabulum; but as to the nature and properties of pabulum, he and Doctor Beale differ absolutely.

To Doctor Beale there is as much difference between living protoplasm and dead pabulum as there is between the ox and his hay. To him living protoplasm alone is protoplasm. No such thing as dead protoplasm is possible. Protoplasm invariably dies into formed material, and formed material may become pabulum. Pabulum does, indeed, again become protoplasm; but the three things I have named are always perfectly distinct, at least there is an absolute gulf between protoplasm and pabulum; and when pabulum becomes protoplasm it is by a sudden, less than instantaneous, leap, and not by a graded progression.

But to Professor Huxley, the mutton, lobster, or bread which he supposes himself to take for the replenishment of his wasted protoplasm, appears to be itself protoplasm, though he speaks of it as dead for the time being, and as if its life-history (whether in biped, quadruped, crustacean, or cereal) depended merely upon the channel into which it chanced to drift, and the motion it happened to acquire, as it was borne along the general stream of organic existence; for he says: "this mutton was once the living protoplasm, more or less modified, of another animal,—a sheep. As I shall eat it, it is the same matter altered, not only by death, but by exposure to sundry artificial operations in the

process of cooking. But these changes, whatever be their extent, have not rendered it incompetent to resume its old functions as matter of life. A singular inward laboratory, which I possess, will dissolve a certain portion of the modified protoplasm, the solution so formed will pass into my veins; and the subtle influences to which it will then be subjected will convert the *dead protoplasm* into *living protoplasm* and transubstantiate sheep into man. Nor is this all. If digestion were a thing to be trifled with, I might sup upon lobster, and the matter of life of the crustacean would undergo the same wonderful metamorphosis into humanity. And were I to return to my own place by sea, and undergo shipwreck, the crustacea might, and probably would, return the compliment, and demonstrate our common nature, by turning my protoplasm into living lobster. Or, if nothing better were to be had, I might supply my wants with mere bread, and I should find the protoplasm of the wheat-plant to be convertible into man, with no more trouble than that of the sheep, and with far less, I fancy, than that of the lobster, Hence it appears to be a matter of no great moment what animal, or what plant, I lay under contribution for protoplasm, and the fact speaks volumes for the general identity of that substance in all living beings. I share this catholicity of assimilation with other animals, all of which, so far as we know, could thrive equally well on the protoplasm of any of their fellows, or of any plant."

This argument was taken up and commented upon somewhat satirically and, as I think, in the main, reasonably, by Doctor Sterling, who has said, with reference to it, "Is it true that every organism can digest every other organism, and that thus a relation of identity is established between that which digests and whatever is digested? * * * * It is very evident that there is an end of the argument if all foods and all feeders are essentially identical both with themselves and with each other. * * * * It is not long since Mr. Huxley himself pointed out the great difference between the foods of plants and the foods of animals. * * * * Mr. Huxley talks feelingly of the possibility of himself feeding the lobster quite as much as of the lobster feeding him; but such pathos is not always applicable; it is not likely that a sponge would be to the stomach of Mr. Huxley any more than Mr. Huxley to the stomach of a sponge.

* * * * We can neither acquire the functions of what we eat, nor impart our functions to what eats us. We shall not come to fly by feeding on vultures, nor they to speak by feeding on us. No possible manure of human brains will enable a cornfield to reason." [18]

On the subject of chemical constitution Professor Huxley says "it will be observed that the existence of the matter of life depends on the pre-existence of certain compounds, namely, carbonic acid, water and ammonia. Withdraw any one of these three from the world and all vital phenomena come to an end. They are related to the protoplasm of the plant, as the protoplasm of the plant is to that of the animal. Carbon, hydrogen, oxygen, and nitrogen are all lifeless bodies. Of these carbon and oxygen unite in certain proportions and under certain conditions, to give rise to carbonic acid; hydrogen and oxygen produce water; nitrogen and hydrogen give rise to ammonia. These new compounds, like the elementary bodies of which they are composed, are lifeless. But when they are brought together under certain conditions they give rise to the still more complex body, protoplasm, and this protoplasm exhibits the phenomena of life. I see no break in this series of steps in molecular complication, and I am unable to understand why the language which is applicable to any one term of the series may not be used to any of the others;" and so he at last comes to ask: "What better philosophical status has *vitality* than *aquosity?*" To which Doctor Sterling replies: "The molecules are as fully accounted for in protoplasm as in water; but the sum of qualities thus exhausted in the latter, is not so exhausted in the former, in which there are qualities due, plainly, not to the molecules as molecules, but to the form into which they are thrown, and the force that makes that form one. * * * * As the differences of ice and steam from water lay not in the hydrogen and oxygen, but in the heat, so the difference of living from dead protoplasm lies not in the carbon, the hydrogen, the oxygen, and the nitrogen, but in the vital organization. In all cases, for the new quality, plainly, we must have a new explanation. The qualities of a steam-engine are not the results of its simple chemistry."

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[18] "As Regards Protoplasm." By James Hutchison Sterling, LL. D. Edinburgh, Oct. 1869, 2d edn., 1872.

Whatever we may think of this discussion. we must perceive that, by this time, the cell doctrine had been wholly lost sight of, and that the protoplasm theory had occupied the entire field, although Doctor Beale was still feebly expressing the hope "that the short convenient word *cell* should not be discarded," and was venturing to "think that the phenomena essential to living matter are only possible in minute masses separated from one another, so that each may be supplied upon its circumference with nutrient materials." But it had become a general tendency to make life an attribute of a *substance* as distinguished from a *form*. As Doctor Sterling said with reference to Professor Huxley, the thing aimed at, as a result of mere ordinary chemical process, was "a life-stuff in mass, as it were in the web, to which he has only to resort for cuttings and cuttings in order to produce, by aggregation, what organized individual he pleases;" or, as he describes it more briefly, protoplasm by the spoonful or toothpickful.

Now this basal matter of life, which was thus to be taken by the spoonful or toothpickful to make a living organism, was at this time, by common consent, looked upon as a homogeneous, structureless substance, not distinguishable in merely physical constitution from other members of the class proteids;—a veritable colloid, differing from other colloids only in the respect of being as ceaselessly active as they are continually passive. Very soon, however, even this doctrine of homogeneousness and structurelessness was attacked; for, as it would seem we might have anticipated, increasing microscopical powers and improving methods of observation began to disclose to some investigators first differences of function in different portions of the heretofore seemingly undifferentiated protoplasm of the lower organisms, and then an actual structure which narrowed the basis of life to a fine net-work within what before had been regarded as a wholly living substance.

This condition of things had not been suspected by Professor Huxley and others who believed that protoplasm as they saw it in the nettle-sting and in the white blood-corpuscle was absolutely the starting-point of structural evolution;—a simple formative, but formless, matter. They were compelled, however, to recognize the fact that one bit of apparently homogeneous living jelly was bound to follow a life-history entirely dis-

tinct from that of another bit of living jelly optically exactly like it; and that the one never would fulfill by accident, and never could be made to fulfill, the destiny of the other. But this difference of function and behavior in forms merely looking alike, they undertook to account for either by purely chemical symbolism, as we have seen Professor Huxley doing, or else by arguments from the laws of molecular physics. Thus Professor Rutherford, at the British Association meeting in 1873, said: "There appears to be no reason for supposing that two particles of protoplasm, which possess a similar microscopic structure, must act in the same way; for the physicist knows that molecular structure and action are beyond the ken of the microscopist, and that within apparently homogeneous jelly-like particles of protoplasm there may be differences of molecular constitution and arrangement which determine widely different properties." Hæckel also had said: "All the immeasurable variety in the most diverse properties of organic bodies perceptible to the senses, which excite and delight our perceptions, is to be traced back to the alike infinitely numerous and delicate differences in the atomic constitution of the albumen-compounds which constitute the plasma of the plastids."[19]

The trouble with these arguments is that they assume that investigation into the composition of protoplasm had really got down as deep as molecular structure. The fact is that the occasion had not yet arisen for a final refuge in what Professor Tyndall has aptly termed "the scientific use of the imagination;" for it was soon proven that the resources of instrumentally-aided eye-sight had been by no means exhausted. Purely optical methods began to develop a necessity for a distinction of parts in what had been regarded as homogeneous, and the introduction of the words "cytoplasma," "hyaloplasma," "polioplasma," "paraplasma," etc., into the nomenclature of the subject, testified to the differentiation which was coming to light.

Professor Goodale has set forth very clearly the changes which have taken place in the botanical phase of this subject during the last twenty years, in his presidential address to the biological section of the American Association, at its recent Toronto meeting. He shows that at the beginning of this period "the following points were regarded as established: 1. All of

[19] "Generale Morphologie."

the activities of the vegetable cell are manifested in its protoplasmic contents ; 2. Protoplasm consists chemically of a nitrogenous basis ; 3. Protoplasm has no demonstrable structure ; 4. The protoplasmic contents in one vegetable cell are not connected with the protoplasmic contents in adjoining cells ; 5. The nucleus and other vitalized granules in the vegetable cell are formed by differentiation from amorphous protoplasm ;" and that, while the first proposition may be considered as finally established, the conception of the second has been considerably modified, and all the others have been completely disproved. He says, further, that "instead of regarding the protoplasmic basis as comparatively simple, it is now known to be exceedingly complex, and to contain numerous cognate proteids, some of which can be identified in the basic mass, others in the nucleus, and others still in the vitalized granules ;" and that the results of various studies "compel us to recognize in protoplasm a substance of bewildering complexity of composition and constitution."

This fact began to be apparent in the animal realm when Heitzmann, Klein and others announced the discovery of an "intra-cellular net-work" in the white blood-corpuscle, the points of intersection of the reticulum being what had been previously called the granules. In a paper read before our New York Academy of Sciences in 1879,[20] Doctor Elsberg called attention to the communication to the Vienna Academy, in 1873, in which Doctor Heitzmann "demonstrated the existence of a net-work in amœbæ, blood-corpuscles of astacus and of triton, human colorless blood-corpuscles and colostrum corpuscles ; and, from direct observation of the changes in the reticulum during the contraction of the living body, announced that the substance constituting the net-work is itself the living matter or bioplasm ;" and Doctor Elsberg himself endeavored to demonstrate a similar structure in the red blood-corpuscles.

I can well remember, as perhaps you also can, the disgusted incredulity with which this new doctrine was received,—an incredulity in which, I confess, I then shared I am not sure that the appearance of a reticulum in the prepared blood-corpuscle is even yet generally accepted as evidence of a normal structure of the kind claimed by Doctor Heitzmann ; but the claim cer-

[20] "The Structure of Colored Blood-Corpuscles." Annals N. Y. Acad. Sci. Vol. I.

tainly gains support from the fact that vegetable histologists are pretty well agreed that a more or less similar reticulum is demonstrable in the protoplasm of plants. Professor Goodale seems to have no doubt on this point, although he thinks that "this conception of protoplasm as a mass composed of a net-work of minutest fibres enclosing in the meshes another substance, presents * * * * great difficulties when we endeavor to explain the movements within the cell;" and that "it is very difficult to explain in any way the so-called wandering of protoplasm outside the cell-wall or into intercellular spaces."

Doctor Heitzmann, however, considers the reticulum or mesh an easy explanation of protoplasmic movements. To him the net-work of living, contractile matter contains in its interstices a lifeless liquid, which, by its contraction, it is able to squeeze out of itself, or from one part to another. Thus, he says, "the liquid held in the meshes, being driven out of the contracted portion will rush into a portion at the time at rest, and will extend this portion in the shape of what has been termed pseudopodia."[21]

In the work from which I have just quoted, Doctor Heitzmann generalizes as follows: "What * * * * was called a structureless, elementary organism, a 'cell,' I have demonstrated to consist only in part of living matter, while even the minutest granules of this matter are endowed with manifestations of life. The cell of the authors, therefore, is not an elementary, but a rather complicated, organism, of which small detached portions will exhibit amœboid motions. * * * * How complicated the structure of a minute particle of living matter may be, we can hardly imagine; what we do know is that the so-called 'cell' is composed of innumerable particles of living matter, every one of which is endowed with properties formerly attributed to the cell-organism."

It having been shown that life hangs upon a web of infinite tenuity, and does not reside necessarily in either a vesicle or a lump, it was a natural and easy step to extend this net-work from tissue to tissue and organ to organ, in an unbroken circuit of vital communication. This step Doctor Heitzmann does not hesitate to take; for, says he, "there is no such thing as an isolated, individual cell in the tissues, as all cells prove to be joined

[21] "Microscopical Morphology." New York, 1883.

throughout the organism, thus rendering the body *in toto* an individual. What was formerly thought to be a cell is, in the present view, a node of a reticulum traversing the tissue. * * * * The living matter of the tissues exists mainly in the reticular stage, and is interconnected without interruption throughout the body."

Again this at first very strange and, for some reason or another, unwelcome doctrine receives support from the investigations of botanists; for, as Professor Goodale remarks, this protoplasmic intercommunication between adjoining cells "has been shown to be so widely true in the case of the plants hitherto investigated, that the generalization has been ventured on that all the protoplasm throughout the plant is continuous." The position to which we have traced this matter is, then, that to the latest biology, in any particular organism, a generally diffused and interconnected substance, simple only in appearance under present optical aids, has taken the place of the circumscribed, more or less isolated and independent, and recognizably complex vesicle which was the physical basis of life to the science of fifty years ago. In the words of Doctor Heitzmann, "according to the former view, the body is composed of colonies of amœbæ: according to the latter, the body is composed of one complex amœba."

Here we must pause to note briefly what effect this abolition of the cell-doctrine has had upon the conception of vitality. I said at the beginning of my address that the protoplasmic theory of life might be traced up-stream to a revolt against the belief in a vital principle received into the organism as a whole,—not evolved by its organs or parts. In other words, the newer tendency was supposed to be distinctly materialistic, as against the older faith which was plainly spiritualistic. According to the earlier conception, every man was a doubly-refracted image,—a bodily person overlying a spiritual person,—the one co-extensive with the other. Substantially the same idea was extended to the lower animals and to plants; whatever the vitalizing essence was, it was a whole, as the animal or the plant was a whole. The manifestation of life in an organism was not looked upon as an aggregate of the vital actions of minor parts, emanating and radiating from them, but as a pervading principle received into the parts, through the whole from without, as a

sponge absorbs water and sucks it into every cavity. Life, in short, was regarded as centripetal, not centrifugal ; and there was thought to be Scripture warrant for this view, in the record of the fact that the Creator, after fashioning the human form from purely inert material, at last breathed into it the breath of life and raised it up a sentient being.

But the tendency of the cell-doctrine was to disintegrate the vital principle,—to drive it into minute and independent centres, —to destroy the long-accepted idea of individuality. In place of one body containing one living spirit, a new conception was introduced, as we have seen, of an infinitely multiple body composed of absolute, though very minute, units, each possessing in itself all the essentials to vitality,—each inhabited by its own little vital spirit.

Now, when Beale announced his discovery of the seat of all vital action in a mere life-manifesting substance, without cell-wall or nucleus, and even, as he imagined, without structure, which substance was contained within every living tissue throughout the organism, he was supposed to have aimed a fatal blow at the materialistic conception of life. But we have observed how Professor Huxley, starting with Beale's ideal living matter, turned the argument again into the materialistic channel and undertook to prove, from Beale's premises, a conclusion in favor of mere chemistry and physics as against Beale's provisional "vital power." We have seen, too, how he shaped his argument to the thesis "all flesh is grass," or, as perhaps he would prefer to say, all flesh is clay, and the whole world is one great laboratory, and its sole shaping and directing powers are the physical and chemical forces ;—men are not different from other animals except in position ; all are but machines and their actions are automatic, originating in the functions not of separate cells, to be sure, but of separate masses, manifesting, in different ways, after all, only modes of one motion, namely, contractility.

Then came the men who dissected and analyzed Huxley's physical basis of life and showed that its bulk and substance is in truth as lifeless as the water in the sponge ; who replaced his life in masses or lumps by what Doctor Sterling had already unwittingly designated as "life in the web." And so we have arrived at a point in our historical survey at which life is supposed literally to hang upon a slender thread, intact throughout,

though infinitely extended and interwoven through the whole organism. Upon this warp the ancient figure of a vital spirit may easily be rewrought ; once more the way is prepared for a re-entrance of the spiritualistic conception of life. The breath of speculation has thus blown upon the surface of truth, and we have seen wave after wave roll by, each in its turn filling the field of vision and obscuring the level horizon beyond. But one wave cannot be more permanent than another, and the last we have looked upon is not in fact the last.

While the protoplasm theory has been assuming the form just mentioned, the cell doctrine also has been taking on an entirely new aspect. The door has suddenly been opened to a whole world of hitherto unknown non-nucleated organisms whose study is now engrossing the attention and monopolizing the energies of investigators everywhere. Bacteriology is the key to present biology. Strangely enough, too, we are once more eagerly searching for a solution of the problem of life through a close scrutiny of the phenomena of death ; for these new organisms, which are found to swarm in unimaginable plenitude, seem to be the counterbalance on the forces of vitality. "Mildew, mould, bacteria, * * * * monads, two thousand of which would go to make up a millimeter, all these microscopic organisms are charged with the great work of re-establishing the equilibrium of life by giving back to it all that it has formed." [22]

To Louis Pasteur belongs the credit for a large part of the labor of investigating the offices and actions of these micro-organisms, or microbes, in the processes of disorganization and dissolution. To him belongs the whole of the credit for reducing these processes to a single genus or type. He first explained to us the *modus operandi* of the formerly mysterious operations of death, decay and putrefaction, with their accompanying and complementary phenomena of resuscitation, nutrition, and reproduction. As M. Radot says, in summing up Professor Pasteur's conclusions on this subject, "All that has lived must die, and all that is dead must be disintegrated, dissolved or gasified ; the elements which are the substratum of life must enter into new cycles of life. If things were otherwise the matter of organized beings would encumber the surface of the earth, and the law of

[22] "Louis Pasteur, His Life and Labors." By his Son-in-law (M. Radot).

the perpetuity of life would be compromised by the gradual exhaustion of its materials. One grand phenomenon presides over this vast work, the phenomenon of fermentation." It was Pasteur who first clearly demonstrated that fermentation is always dependent on the life of a microscopic organism : that in fact it is "simply a phenomenon of nutrition." As Professor Tyndall says, in his introduction to the work from which I have just quoted : "with true scientific instinct, he closed with the conception that ferments are, in all cases, living things, and that the substances formerly regarded as ferments are, in reality, the food of the ferments ;" or, in the words of M. Radot, " the organism eats one part of the fermentable matter." Here, then, we have two of Beale's physiological elements, a speck of bioplasm and pabulum, translated into a uni-cellular ferment and its fermentable habitat.

Now, side by side with the new philosophy of fermentation there has developed a revolutionary idea in pathology, which has come to be known as the germ theory of disease. At first this theory was, as usual, pushed to an untenable extreme, in an assertion that all diseases were immediately caused by microbes which were introduced into the system from without and which produced their effects by a direct attack upon the tissues in which they lodged. As a result of the new philosophy of fermentation, however, it was soon found that microbes, acting as ferments, produced, by their action upon fermentable substances, peculiar chemical compounds, resembling the vegetable alkaloids, and which are now called ptomaines. This discovery led to a pretty lively discussion as to whether the microbe or the ptomaine was the immediate cause of the disease which ensued upon the introduction of a microbe into a living body ; and not until a ptomaine had been separated from its associate microbe and, by inoculation, had been caused to produce the disease previously supposed to be dependent on the presence of the microbe itself, was it admitted that, in some cases at least, the microbe was only an indirect cause of the disease, and the ptomaine was the more immediate.

It then became apparent that there were still two quite distinct classes of diseases, the infectious, originating without, and the autogenous, originating within, the organism. Plainly the latter did not easily come under the germ theory. It was next dis-

covered that even in the healthy animal system alkaloids were being constantly compounded, which could not be clearly distinguished from the vegetable alkaloids, or ptomaines. For these the name leucomaines was invented. But, having found that ptomaines were always products of fermentation, it was a natural step to the assumption that leucomaines must be results of a like process; and good reasons quickly appeared for this generalization. Fermentation, during which ptomaines are produced, being a phenomenon of nutrition, as between a unicellular organism and its pabulum: the organism, the ferment, being introduced from without into the fermentable substance;—analogy easily led to the conclusion that the production of leucomaines is a phenomenon of nutrition as between the normal constituent element of the body—(whether the old-fashioned cell, or the new-fashioned protoplasmic reticulum),—and its nourishing fluid.

Professor Joseph LeConte has recently called attention to this latest tendency of the cell doctrine, on which subject he says: "We have seen that ptomaines are alkaloids of albuminoid decomposition generated in the presence and under the guidance of microbian life. Now there is going on continually in the animal body, as a strictly physiological process, albuminoid decomposition (wasting of the tissues) in the presence and under the guidance of cell life. This also, as might be expected, produces poisonous products * * * * If they are not also usually deadly to the animal body, it is only because they are continually being eliminated by appropriate organs."[23] And this elimination, we may well imagine, is a result of the operation of natural selection, which has not yet produced immunity against all ptomaines, as it has against most leucomaines.

As it is not my purpose to discuss the germ theory itself, I shall not follow this subject further. Sufficient has been said to indicate the direction in which the cell doctrine, or perhaps I should say the protoplasm theory, is once more moving.

I must therefore bring my already too lengthy sketch to an end although, before actually closing, I cannot refrain from summarizing some of the conclusions which seem to me to be justified by the historical survey which I have endeavored to make.

First, then, the original idea of the cell, as propounded by

[23] Letter to "Science," Nov. 8, 1889.

Schleiden and Schwann, has gradually faded away. Such cells as they actually saw, do, indeed, still exist; but the cells they thought they saw have been deprived of all that were by them considered essentials. The attention of the defenders of the cell doctrine has been forced from cell-wall to nucleus, from nucleus to nucleolus, from nucleolus to plastids, from plastids to germinal points; a mathematical reduction to mere position without dimension;—a subjective conception, not an objective realization. Parenchyma cells in plants, and epithelial cells in animals, are no less constituent rooms in an organic building than they formerly were; but to the later science they are not the fundamental, autonomous units they were to the earlier science. Fifty years ago such cells as these stood upon the horizon of biological insight. To-day our vision extends far beyond them. To-morrow it will doubtless reach to distant points now even unimagined. At any rate, it is safe to say that, in the present condition of science, we have no actual knowledge of an ultimate unit, either physical or physiological. Science, nevertheless, like the youth in search of the gold at the end of the rain-bow, is ever pressing forward to fancied finalities, only to find new starting-points for a continuation of the race.

Second, no one has ever really seen Doctor Beale's ideal living matter. What he saw and called bioplasm was simple enough, compared with Dujardin's sarcode; but, like sarcode, his bioplasm has proved to be exceedingly complex. At this moment the idea embraced in his designation, *germinal matter*, is applicable, if to any actually visible thing, to a mere skeleton of his original bioplasm. Next year it may be applicable to only a small part of this attenuated reticulum;—and so on *ad infinitum*.

Third, Huxley's physical basis of life is pushed ahead again into the realm of the imagination. There probably is a physical basis, but it is not the particular basis Professor Huxley had in view; because the protoplasm of the nettle-sting, the protoplasm of the globergerina, and the protoplasm of the blood-corpuscle are clearly proven to be different protoplasms, chemically as well as physically and physiologically. Moreover, it is pretty certain that one protoplasm cannot be converted into another, except through the process of dying, becoming pabulum, being decomposed by fermentation, converted into new compounds and appropriated and assimilated;—which is a somewhat compli-

cated and, withal, mysterious operation. Professor Huxley's easy transubstantiation of protoplasm known as boiled mutton into protoplasm known as human brain-tissue, is consequently a myth.

This leads me to say, *Fourth*, that there appears to be no one visible and tangible substance to which the name protoplasm is rigidly and exclusively applied. As soon as we withdraw it from a purely philosophical concept, we find it attached to almost every sort of crude material which can by any possibility enter into the composition of a living structure. The name is, in particular, applied to any and every substance of a proteinaceous nature. In fact, with some writers, protoplasm is pretty nearly synonymous with proteid. Botanists are specially inexact in this respect. Having appropriated the name albumen for a substance not at all albuminous, they now seem to have adopted protoplasm as a designation for materials anything but protoplasmic. Beale's protoplasm, you will remember, is homogeneous, and structureless, and always contains much water. Professor Geddes, however, speaks of the "comparatively solid, almost brittle, state of the quiescent protoplasm of some seeds;"[24] and Professor Goodale tells us that the protoplasm of many kinds of seeds and spores can preserve its vitality during exposure to dry air at a temperature above that of boiling water under which condition he admits that it would be thoroughly dessicated.[25] "The consistence of protoplasm," he says, "depends on the amount of water which it contains. Thus in dry seeds it is nearly as tough as horn, while in the same seeds during germination it becomes like softened gelatin."[26] In another place he speaks of "inactive, amorphous protoplasm, as it sometimes exists in certain cells, where it is simply a tough, shapeless mass."[27] Fancy Doctor Beale's germinal matter reduced to the consistency of horn, or even to that of softened gelatin!

But, *Fifth*, if in some seeds (the so-called vegetable ivory, for example,) the only vitalizable substance is a solid, brittle, tough and horny proteid, it looks as if we had struck an inexplicable puzzle in the sudden appearance of the semi-fluid plastic proto-

[24] Encyclopædia Britannica; article, Protoplasm.

[25] Gray's Physiological Botany, p. 205.

[26] Ibid, p. 28.

[27] Ibid, p. 44.

plasm when the embryo begins to grow. Doctor Sterling, as well as Doctor Beale, insisted that vitality was an inherent and inseparable attribute of real protoplasm, and that consequently there could not be such a thing as dead protoplasm. I doubt whether, under their definitions, there can be even a dormant protoplasm; for, in truth, what is dormant life, which this implies? Is it not in effect dead life? That is to say, is it not the essential sign of life that it is not dormant? Beale urges that there is no intermediate step between dead matter and living matter. Matter, he argues, is either wholly alive or wholly dead. Latent life, then, is at bottom only one of the philosophical figments of which we have already heard. Suspended animation may be possible in a complicated organism, but if we are to follow the philosophers down to a basal life-stuff, we cannot logically admit any factor into the problem but matter and life. In other words, the only admissible alternative is matter plus vitality or matter minus vitality.

This, then, brings us to the point to which my address of a year ago brought us,—to the impassable gulf between the not-living and the living. This is the perennial mystery of mysteries to whose brink every thorough scientist and every deep philosopher sooner or later comes, but beyond whose thick darkness no human eye can see, and under whose appalling silence even the wisest man must stand dumb.

SYNOPSIS OF THE CRETACEOUS FORAMINIFERA OF NEW JERSEY.

Part I. Review of Previous Investigations.

BY ANTHONY WOODWARD.

(*Presented December 20th*, 1889.)

The embodiment of this paper is to bring together all the work that has been previously done, and the remarks that have been made on the Cretaceous Foraminifera of New Jersey, from 1833–1889, by giving a reproduction of such parts of the various interesting and valuable papers of Isaac Lea, Jacob Whitman Bailey, Samuel George Morton, Charles Lyell, William M. Gabb, Auguste Emanuel Reuss, Fielding Bradford Meek, Louis F. De Pourtales, Herr Hermann von Credner, Thomas Rupert Jones and William Kitchen Parker as are scattered through literature, not always accessible.

1833. Isaac Lea. Contributions to Geology, 219, 220. Description of a new Genus of the Family *Spherulacea* of Blainville, from the Cretaceous deposit of Timber Creek, New Jersey.

Genus Palmula (nobis).

Description. Shell palmate, with angular striæ, which indicate the interior chambers ; aperture terminal.

Observations. Two specimens of the shell on which I propose to found this genus, were found by me, about four years since, in the Cretaceous deposit of Timber Creek, New Jersey. In its characters it approximates most closely to the genus *Saracenaria* of Defrance. Manuel de Malacologie, Blainville, 370. The oval form, the possession of a carina, and the absence of an aperture in that genus, prohibit our shell being placed with it. The *Palmula* also resembles the genus *Textularia* of the same author, and might, perhaps, with propriety be placed between these two genera.

P. sagittaria. Pl. vi., fig. 228.

The small figure is of the size of nature.

Description. Shell depressed, sagittate, rounded on the edges, with about six angular striæ, which indicate the interior chambers; mouth terminal, oval, sublabiate, Diameter .05, Length .2, Breadth .1 of an inch.

Observations. The two specimens differ somewhat in outline, the larger one being more elliptical. In both the angular striæ become obsolete at the base, being most distinct on the superior part.

1841. J. W. Bailey. Fossil Foraminifera in the Green Sand of New Jersey. Amer. Journ. Sci. xli. 213, 214.

In a recent visit to the Cretaceous formation of New Jersey, he has brought to light the interesting fact that a large portion of the calcareous rock, defined by Prof. H. D. Rogers as the third formation of the upper secondary, is made up, at the localities where he examined it, of great quantities of microscopic shells, belonging to the Foraminifera of d'Orbigny, which order includes those multilocular shells, which compose a large part of the calcareous sands, etc., of Grignon and other localties, in the tertiary deposits of Europe. Since the minute multilocular shells above alluded to were discovered, Dr. Torrey and Prof. Bailey have together examined specimens of limestone from Claiborne, Alabama, and have found in them Foraminifera, of forms apparently identical with those occurring in New Jersey. None of this order, except the genus *Nummulite*, have heretofore been noticed in our green-sand formation.

1842. S. G. Morton. Description of some new species of Organic Remains of the Cretaceous Group of the United States. Journ. Acad. Nat. Sci., viii. 214, 215, pl. xi. fig. 5.

Genus Planularia.

P. cuneata. Pl. xi. fig. 5. Shell ovate, slightly angulated in the middle; one side slightly concave, with concentric lines, which are angular in the centre of the disk. Length three-tenths of an inch.

From the middle cretaceous strata of New Jersey, where it was found by Mr. Conrad.

No locality given.

1845. Charles Lyell. Notes on the Cretaceous Strata, of New Jersey and other parts of the United States bordering the Atlantic. Quart. Journ. Geol. Soc. Lond., i. 56, 57, 64.

In an excursion which I made in New Jersey, in September, 1841, in company with Mr. Conrad, we went first to Bristol, on the Delaware, next, by Bordentown, to New Egypt, and returned by Timber Creek, recrossing the Delaware at Camden.

In the upper or straw-colored limestones, I found on the banks of the Timber Creek, twelve miles southeast of Philadelphia, six species of corals. The same calcareous formation also abounds in Foraminifera, characteristic of the chalk, comprising, among others, the genera *Cristellaria*, *Rotalina* and *Nodosaria*.

I saw the formation in question, on the banks of Timber Creek, a stream which flows into the Delaware three miles below Philadelphia.

The principal locality is twelve miles southeast of Philadelphia, about a mile and a half south of the village of White Horse, Gloucester County, New Jersey.

Notice of the Foraminifera by Lyell. (Figures *Rotalina* and *Cristellaria*).

The above are figures of two genera of Foraminifera from the upper beds at Timber Creek, alluded to in the paper. I am not aware that any attention has hitherto been paid to the fossil foraminifera of American Cretaceous strata, to which I find no allusion in Dr. Morton's works. They are very abundant in the coralline rock of Timber Creek. Mr. Forbes has examined some of them for me, and these belong to the genera *Cristellaria*, *Rotalina* and *Nodosaria*. All these genera occur in the chalk of Europe. One of my American species of fossil *Cristellaria* is specifically identified by Mr. Forbes with *C. rotulata* of d'Orbigny, which occurs in England, France and Germany, ranging from the upper greensand to white chalk. It is another instance of species found most abundantly in Europe, recurring in American chalk. There are two other species of the same genus at Timber Creek, one of them very large. There are two species of *Nodosaria*. The *Rotalina*, which is very abundant, is closely allied to species of our chalk.

1845. Chas. Lyell. Travels in North America, i. 64.

He found, in the upper, or straw-colored limestone, on the banks of the Timber Creek, twelve miles southeast of Philadelphia, six species of corals and several echinoderms, chiefly allied to upper cretaceous forms. The same calcareous stratum also abounds in Foraminifera, characteristic of the chalk, comprising, among others, the genera *Cristellaria*, *Rotalina* and *Nodosaria*.

1856. J. W. Bailey. On the Origin of Greensand, and its formations in the Oceans of the present epoch. Proc. Bost. Soc. Nat. Hist., v. 365, 366.

The formation of the Greensand consists in a gradual green-colored, opal-like mass, which forms therein as a cast. It is a peculiar species of natural injection, and is often so perfect, that not only the large and coarse cells, but also the very finest canals of the cell-walls, and all their connecting tubes are thus petrified, and separately exhibited. By no artificial method can such fine and perfect injections be obtained.

He mentions among his observations, that the yellowish limestone of the cretacecus deposits of New Jersey occurring with *Teredo tibialis*, etc., at Mullica Hill, and near Mount Holly, is very rich in greensand casts of *Polythalamia* and of the tubuliform bodies above alluded to.

1860. W. M. Gabb. Descriptions of New Species of American Tertiary and Cretaceous Fossils. Journ. Acad. Nat. Sci., ser. 2. iv. 402, 403, pl. lxix. figs. 40, 41.

I have recognized a number of species of foraminifera, in a marl from near Mullica Hill, N. J., of the same age as Timber Creek limestone (upper part of No. 5 of Meek and Hayden,) abounding in corals, the most common of which is *Eschara digitata*. The matrix is fortunately not so hard as that at Timber Creek, and both the corals and foraminifera are much better preserved. I shall not describe any at present, except the beautiful *Dentalina*, given below. I expect, however, at some not very

distant period to characterize them. I have not yet seen *Cristellaria rotula*, said by Lyell to occur at Timber Creek, although I have examined several hundred specimens.

DENTALINA, d'Orb.

D. pulchra. Pl. lxix, figs. 40, 41. Elongated, very slightly arcuate; cells large, more convex towards the large extremity; diameters of cells equal; surface marked by about ten heavy, longitudinal ribs; sutures obliterated; opening small, tubulate and inclined in the direction of the curve.

Dimensions. Length about .25 in., greatest diameter .03 in. Locality —Near Mullica Hill, N. J. My collection. Rare.

1861. A. E. REUSS. Die Foraminiferen des senonischen Grünsandes von New Jersey. Paläontologische Beiträge. Sitzungsberichte d. kais. Akad. d. Wissenschaft in. Wien., xliv. 334–342, pls. i–viii.

(Translation.)

The Foraminifera of the Cretaceous Greensands from New Jersey.

From the materials furnished me for examination, I have to thank Dr. Hörnes, Director of the Imperial Cabinet of Mineralogy at Vienna, Dr. Krantz of Bonn, and especially Prof. Ferd. Römer of Breslau. The specimens from the first two contained but few foraminifera; those from Prof. Römer were quite rich in the same. Unfortunntely, however, they were for the most part not well preserved and the more fragile forms were present only in fragments.

The following is a list of the species found. They all belong to the polymerous Foraminifera, and the few species which appear to me to be new, I have described and figured.

1. RHABDOIDEA, Schltz.

a) NODOSARIDEA (m.)

a) **Nodosaria**, d'Orb.

1. *N. polygona*, Rss. Zeitschr. d. deutsch. geolog. Gesellsch., 1855, 265, pl. vii. figs. 7, 8. Fragments, rare. They are very often found however, in the upper Cretaceous of Mecklenburg.

2. *N.* sp. with globular chambers, separated by deep sutures, which are covered with numerous fine longitudinal ridges. The first chamber is equal in size to the following one, and ends in a very short, central spine. I saw only a fragment in which the last chamber was wanting.

b) **Dentalina**, d'Orb.

1. *D. gracilis*, d'Orb. Mém. de la soc. gêol. de France, iv. 1, 14, pl. i. fig. 5. Very rare elsewhere in the upper chalk formations down to the "Pläner." Very widely distributed.

2. *D. colligata*, N. sp. Pl. vii. fig. 4. Approaching many species of *Marginulina.* Little bent, obtuse below, with six to seven chambers,

the first small, rounded, and scarcely larger than the next, from which externally, it does not appear to be separated. The remaining chambers increase upward gradually in breadth, with unequal sides. The ventral side is somewhat more ventricose than the dorsal side, and is separated by very small and shallow oblique sutures. On the concave dorsal side, all the chambers are united, as it were, by a small, narrow, smooth, slightly elevated ridge, upon which the division of the chambers is scarcely visible. The first chamber shows a slight tendency to curve forward; the last, which is very oblique, ends at the dorsal angle in a short thick spine. Very rare.

3. *D. Steenstrupi*, Rss. See page 326. Very rare.

4. *D. confluens*, N. sp. Pl. vii. fig. 5. The shell (Gehäuse), which may be 3 mm. long, is rather thick, slightly bent, sometimes compressed, and consists of seven chambers, in the first of which the boundaries are not to be made out from the external appearance. Only the last chambers, which are slightly higher than broad, are marked off by very shallow sutures. They decrease in size downwards, but slowly, the lower extremity however, diminishing abruptly to form the short spine, the latter being sometimes directed backwards. The chambers are covered with 16–20 very narrow abrupt, longitudinal ridges, these are often irregularly sinuous, and increase in number, from below upward, by the insertion of new ones, or, by bifurcation, they are separated by narrow deep furrows between them. The last, very oblique, chambers run out into a very short spine which almost points backward. Very rare.

b) Frondicularidea (m.)

Flabellina, d'Orb.

Fl. cordata, Rss. Sitzungsber. d. k. Akad. d. Wiss., xl. 216. Very rare.

2. CRISTELLARIDEA, Schltz.

Cristellaria, Lam.

a) Marginulina, d'Orb.

M. ensis, Rss. Die Verstein. der böhm. Kreideform., i. 29, pl. xii. fig. 13, pl. xiii. figs. 26, 27. Very rare. Frequent, however, in the upper cretaceous of other countries down to the "Pläner." England, Westphalia, Bohemia, Galieia, etc. Sitzungsber. d. k. Akad. d. Wiss. in Wien., xl. 207.

b) Cristellaria, d'Orb.

1. *Cr. intermedia*, Rss. var. Die Verstein. der böhm Kreideform., i. 33, pl. xiii. figs. 57, 58, pl. viii. fig. 2. The American specimens differ from the Bohemian in forming a more distinct and larger spiral, and in having the last chambers separated by deeper sutures, while the limits of the first ones are not externally visible. Very rare.

2. *Cr. Baylei*. N. sp. Pl. vii. fig. 7. Diameter 0.77 mm. Shell circular, moderately compressed, lens-shaped, with a sharply, keeled dor-

sum. Nine narrow strongly arched chambers, with low, but well defined septa, which run together in a central, small, low, irregular umbilicate disk. Aperture oval, cut in deeply two-thirds of the way up, through the next to the last whorls, almost forked, margined on both sides by a narrow ridge. Very rare.

3. *Cr. rotulata*, Lam. sp. L. c. 326. Rare.

c) **Robulina**, d'Orb.

R. trachyomphala, Rss. Haidinger's gesamm. naturwiss. Abhdl. iv. 1, 34, pl. iii. fig. 12. Rare. More frequent in the mucronate marl of Nagorzani at Lemberg. Young individuals have only 5–6 chambers, and a very small indistinct umbilicate disk. Some specimens are slightly keeled at the back.

3. LITUOLIDEA (m.)

Haplophragmium, Rss.

1. *H.* sp. A nonionian form, with six arched chambers separated by deep sutures. Shell very rough with small, roundish nonionian aperture. Only one specimen.

4. ROTALIDEA, Schltz.

Rotalia, Lam.

1. *R. nitida*, Rss. Sitzungsber. d. k. Akad. d. Wiss. in Wien., xl. 222. Very rare. Elsewhere occurring in the "Mucronaten und Quadraten Schichten," and in the "Pläner."

2. *R. Micheliniana*, d'Orb. Mém. de la. Soc. géol de Fr., iv. 1, 31, figs. 1–3. Very rare to the "Pläner." Also occurring in the upper Cretaceous of other countries down.

3. *R. polyraphes*, Rss. Haidinger's gesamm. naturwiss. Abhdl., iv. 1, 35, pl. iv. fig. 1. Very rare. Common in the mucronate and quadrate layers, and in the "Pläner" of other countries, rare in the Cretaceous and in the Gault. Numerous localities are mentioned in the Sitzungsber. d. k. Akad. d. Wiss. in Wien., xi. 77

4. *R. Mortoni*, n. sp. Pl. viii. fig. 1. Common. Similar to *R. polyraphes*, Rss., and even more so to *R. lenticula*, Rss.—Die Kreideverstein. Böhmens, i. 35, pl. xii. fig. 17—but much larger than the last, more curved on the spiral side, with numerous and more narrow chambers. Diameter reaches 0.77 mm. The shell is depressed, lens-shaped, with an acute margin, both sides somewhat curved, the umbilicate side more strongly. On the spiral side usually only the last whorl is separated by a narrow but rather deep suture; the older two are but seldom distinguishable externally, and are covered by a calcareous incrustation, which is permeated by porous canals of varied sizes; nine to ten chambers in the last whorl, of which only the last two or three are separated by distinct sutures. They are only slightly curved. The others are usually indistinguishable externally. The umbilicate side shows in its centre either a very

narrow and shallow depression or none at all, or in place of it a small, flat disk-like elevation which is very finely porous. The chambers appear upon this surface as narrow triangles, somewhat curved, the sutures more distinct, as shallow lines. The porous canals, of the spiral side, are somewhat wider than the umbilical side. The aperture is a short opening situated far below the peripheric border.

5. *R. Karsteni*, Rss. Zeitschr. d. deutsch. geolog. Gesellsch., 1855, 273, pl. ix. fig. 6. Very rare.

Rosalina, d'Orb.

1. *R. ammonoides*, Rss. Reuss in Haidinger's gesamm. naturwiss. Abhdl., iv. 1, 36, pl. iv. fig. 2. Very rare. More frequent elsewhere in the upper chalk-beds, down to the Cretaceous.

2. *R. Bosqueti*, n. sp. L. c. 316, pl. iii. fig. 1. Very rare. Also in the chalk-tufa of Mastricht.

Truncatulina, d'Orb.

1. *Tr. convexa*, Rss. L. c. 331. Very rare. Is very variable, often bent and not always so arched as in the figure referred to on the above-mentioned page. Pl. iv. fig. 4.

2. *Tr. De Kayi*, n. sp. Pl. vii. fig. 6. Very rare. The shell which is only 0.49 mm. in diameter, is circular; the spiral side smooth, and only the last chamber slightly arched, with three whorls and a wrinkled upper surface. The umbilicate side arched, regular, with eight small curved chambers, of which only the last are marked off by distinct sutures. The surface coarsely punctate.

5. POLYMORPHINIDEA, d'Orb.

Bulimina, d'Orb.

1. *B. tortilis*, n. sp. Pl. viii. fig. 3. Frequent. A peculiar small species, at the most 0.52 mm. long, triangular pyramidal, with somewhat concave sides, and three longitudinal edges, which gradually become thicker and more obtuse from below upward, and which do not run directly up, but turn gradually in their course so that the whole shell seems twisted. Five whorls, the first ones very small, each consisting of three small semilunate curved chambers; the older ones externally, scarcely separable, slightly arched; the latter ones rapidly increasing in size, and becoming more strongly arched. The orifice, a short elliptical aperture, beginning immediately under the obtuse point of the last chamber, and running down toward the lateral surface of the shell.

2. *B.* sp. indet. Similar to *B. pupoides*, d'Orb.,—Foram. foss. du bass. tert. de Vienne, pl. ii. figs. 11, 12,—with an elongated, smooth irregular shell, with a roundish transverse section. Only one incomplete specimen.

Polymorphina, d'Orb.

a) **Globulina**, d'Orb.

1. *Gl. globosa*, v. Mstr. L. c. 318. Very rare.

2. *Gl. lacrima*, Rss. Haidinger's gesamm. naturwiss. Abhdl., iv. 1, 43, pl. v. fig. 9. Very rare, as in the mucronate marls of Lemberg.

b) Guttulina, d'Orb.

G. cretacea, Alth. L. c. 319. Very rare. A more slender, strongly pointed variety.

c) Polymorphina, d'Orb.

1. *P. subrhombica*, n. sp. Pl. vii. fig. 3. Very rare. The shell 0.98 mm. long, rhomboidal in outline, obtusely pointed to the same extent on both sides, the transverse section narrowly elliptical, the margins angular. There are to be seen externally only four slightly arched, double rows of alternating oblique chambers. Sutures linear, obscure, especially the lower ones. Orifice radiated. The species closely resembles *P. ovata*, d'Orb. Foraminifera du bass. tert. de Vienne, pl. xiii. figs. 1–3. From the miocene strata of the Vienna Basin, and with the oligocene.

2. *P. regularis*, v. M. Reuss, Sitzungsber. d. k. Akad. d. Wiss., xviii. 247, pl. vii. figs. 70–73. It is, however, sufficiently distinct from both.

From the preceding list it will be seen that I have thus far found 28 species of Foraminifera in the Cretaceous Greensand of New Jersey. From the many indeterminable fragments of which I could not possibly determine the genus, the number is undoubtedly greater. From the above number three species, which could not be positively decided on, must be omitted therefore, leaving only 25 species, of which 7—*Dentalina confluens*, *Dentalina colligata*, *Cristellaria Baylei*, *Rotalia Mortoni*, *Truncatulina De Kayi*, *Bulimina tortilis* and *Polymorphina subrhombica*—have, hitherto, not been discovered elsewhere. There remains for comparison only 18 species. They are all collected in the upper Cretaceous of other countries, and 5 of them—*Robulina trachyomphala*, Rss., *Rosalina Bosqueti*, Rss., *Truncatulina convexa*, Rss., *Globulina lacrima*, Rss., and *Guttulina cretacea*, Alth.—are exclusive in these beds.

Four species—*Nodosaria polygona*, Rss., *Dentalina Steenstrupi*, Rss., *Cristellaria intermedia*, Rss., and *Rotalia Karsteni*, Rss.—are found in other countries in the Cretaceous beds also. Five species—*Dentalina gracilis*, d'Orb., *Rotalia nitida*, Rss., *Rotalia Micheliniana*, d'Orb., *Globulina globosa*, v. Mstr. and *Marginulina ensis*, Rss.—extend into the "Pläner." *Globulina globosa*, however, also extends upward into the Oligocene and Miocene Tertiary beds. *Rosalina ammonoides* and *Fallina cordata*, Rss. extend from their vertical range and mucronate bed into the Cretaceous, while *Cristellaria rotulata*, Lam. sp. and *Rotalia polyraphes*, Rss. are found as low as the "Gault."

In the Cretaceous Greensand of New Jersey the Rhabdoidians and the Nodosaridians are represented by 6, the Frondicularidians by 1, the Cristellaridians by 5 species, the Lituolidians by 1, the Rotalidians by 9, and finally the Polymorphinidians by 6 species. The Family of Rotalidians, therefore, furnishes the greatest number of species, while the Rhabdoidians and Polymorphinidians follow next in order. The most numerous species are those belonging to the genera *Rotalia* (5) and *Dentalina* (4). With

the exception of *Rotalia Mortoni* and *Bulimina tortilis* (both new species), of which numerous examples are found, the remainder appear seldom.

Most of them however are very rare. With the exception of the peculiarly formed *Bulimina tortilis*, all the remaining species offer nothing remarkable in their external appearance. They belong to the ordinary, universally distributed, well-known types.

The reference in the description of *Cris. rotulata*: for which the reader is refered to p. 326, is as follows:

1. *Cr. rotulata*, Lam. sp, d'Orb. mém. de la Soc. géol. de France, iv. 1, 26, pl. ii. figs. 9, 15–18. This species, which is commonly distributed in the Cretaceous, occurs quite frequently, also in the chalk of Rügen, and in specimens of unusual size. The orifice is not stellate in any of the specimens at hand. In one, after often repeated and close examination, I could not discover any larger orifice.

I have mentioned numerous localities where this cosmopolitan species can be found, in my Monograph on the Foraminifera of Westphalian chalk formation. Sitzungsber. d. k. Akad. d. Wiss. in Wien., xl. 70.

The description of *R. Bosqueti*. on p. 316, is as follows:

2. *R. Bosqueti*, n. sp. Pl. iii. figs. 9, 1. Rare. Differing from the ordinary *Rosalina* type, more like many Rotalidæ with flat oval shells 0.7 mm. long, broadly oval, strongly depressed, rounded angular edges, very moderately arched spiral side, and somewhat pressed in umbilicate surface. The spiral side shows but two whorls, of which the second increases rapidly in breadth, and presents 7–8 rather broad, slightly curved chambers, which are separated by linear partially obscure sutures. The central volution not externally divided into chambers on the underside, which has a moderately broad umbilicus. Only the last large chamber somewhat protruded. The remainder of the shell is somewhat hollowed out toward the centre. The slightly curved suture narrow, but rather deep. The surface of the shell covered with quite large pores.

1864. F. B. Meek. Check-List of the Invertebrate Fosslls of North America. Cretaceous Formation, Smithsonian Mis. Coll., 177, p. 1.

SUBKINGDOM PROTOZOA.

CLASS RHIZOPODA.

ORDER FORAMINIFERA.

LAGENIDÆ.

2. *Phonemus* (*Cristellaria*) *rotulatus*, (d'Orb.?) Meek.
3. *Phonemus* (*Flabellina*) *cuneatus*, (Morton) Meek.
4. *Phonemus* (*Flabellina*) *sagittarius*, (Lea) Meek.
5. *Phonemus* (*Dentalina*) *pulcher*, Gabb.

Notes and Explanations. (Page 31.)

(Cretaceous.)

3 = *Planularia cuneata*, Morton, Jour. Acad. Nat. Sci., viii. 214, pl. xi. fig. 5.

4 = *Palmula sagittaria*, Lea, Am. Phil. Soc., (1833) Contrib. Geol., 218, pl. vi. Dr. Carpenter unites *Cristellaria*, *Flabellina*, *Dentalina*, *Nodosaria &c.*, as members of a single genus, for which he uses the name *Nodosaria*. It may be at least convenient, however, to retain these names in a subgeneric sense ; but, in either case, we should think Montfort's older name *Phonemus*, should stand for the entire group.

6 and 7.—I have not been able to find by whom these two species were described, but believe it was by Ehrenberg.

1868. F. B. Meek. Synopsis of the Invertebrate Fossils of the Cretaceous Formation of New Jersey. Appendix A., Geology of New Jersey, 721.

SUBKINGDOM PROTOZOA.

CLASS RHIZOPODA.

ORDER FORAMINIFERA.

LAGENIDÆ.

Phonemus (*Flabellina*) *cuneatus*, Morton, sp. Meek. Cretaceous check-list, 1. *Planularia cuneata*, Morton, Jour. Acad. Nat. Sci., ser. i. viii. pl. xi. fig. 5.

Phonemus (*Flabellina*) *sagittarius*, Lea, sp. Meek. Cretaceous check-list, 1. *Palmula sagittaria*, Lea, Amer. Philos. Soc., (1833) Contrib. Geol., 218, pl. vi. fig. 228.

Phonemus (*Dentalina*) *pulcher*, Gabb. Jour. Acad. Nat. Sci., ser. 2, iv. 402, pl. xviii. figs. 40, 41. Meek Cretaceous check-list, 1.

1869. Louis F. De Pourtales. The Gulf Stream. Characteristics of the Atlantic Sea-bottom off the Coast of the United States. U. S. Coast Survey, 1869. (1872) 221, 222.

Off Long Branch and off Rockaway Beach, near the entrance to New York Bay, the sand contains a large mixture of black grains. They are greensand grains or glauconite, casts of the shells of Foraminifera from the greensand formation of New Jersey, and have been washed out, either from the shore or from an outcropping of the beds under the sea-level.

1870. T. Rupert Jones, & W. Kitchen Parker. On the Foraminifera of the Family Rotalinæ (Carpenter) found in Cretaceous Formations ; with Notes on their Tertiary and Recent Representatives. Quart. Journ. Geol. Soc. Lond., xxviii. 103–132.

On page 108 they refer to A. E. Reuss. ——— Die Foraminiferen des senonischen Grünsandes von New Jersey, Palæontologische Beiträge, Sitz. math.—naturw. d. k. Akad. Wiss. in Wien, xliv. 334–340 (1861).

The following synonymy is made.

1. Pl. viii. fig. 1. *Rotalia mortoni* = *Planorbelina Ungeriani.* Thick sub-variety.
2. Pl. vii. fig. 6. *Truncatulina Dekayi* = *Truncatulina lobatula.* Neat form.

On page 121.—" *Pulvinulina repanda* (proper) is represented in the Chalk of Masstricht, but in none of the other cretaceous beds. It is rare in the Tertiaries of our Table (occurring only in the Pliocene), but is scattered throughout the Atlantic. *P. auricula* existed in the Nummulitic sea, abounded in the mid-Tertiary times, and, living now, is abundant in some places ; but it is wanting in the chalk. *P. Menardii*, however, was one of the early representatives of the genus. In New Jersey (North America) it occurs in the Greensand. With us it begins with the white chalk, and has continued with increased prolificness till now. *P. Schreibersii* occurs sporadically in the Greensand of New Jersey."

On page 123, pl. ii. —— the Range of Recent, Tertiary, and Cretaceous Rotalinæ. You will notice three species as being found in the Greensand of New Jersey. *Planorbulina conical*, *P. nautiloid*, and *P. plano-convex.*

1870. Herman von Credner. Die Kreide von New Jersey. Zeits. d. D. Geol. Ges., xxii. 191–251.

This article is a general review of the Cretaceous formation of New Jersey, Geological and Palæontological. On page 214 the author gives under Amorphozoa a description of *Flabellina cordata*, Reuss, and *Nodosaria sulcata*, Nils. of which the following is a translation.

Flabellina cordata, Reuss. Böhm. Kr., i. 32, pl. viii. fig. 39.
Frondicularia ovata, Röemer, Kr., 96, pl. xv. fig. 9.

Elliptical, narrowly compressed, about 15 chambers with bow shaped partition-walls ; the first, smallest chamber slightly nodose arched.

Rare in the bryozoan beds at Brownville.

Nodosaria sulcata, Nils.

Römer, Kr., 95.

Nod. Zippei, Reuss. Böhm. Kr., i. 25, pl. viii. fig. 1.

This handsome bodkin-shaped elongated foraminifer is on an average marked by 12 deep constrictions and appears in examples 18 mm. long. The small central, beak-shaped extension of the uppermost chamber and its aperture for the emission of the sarcode are seldom preserved.

Common in the bryozoan bed at Brownville and Turtle Hill.

N. B.—To follow :

Part II. Original Investigations, and remarks.

This part of the paper will consist of the determinations, additions and remarks on the various species found in material collected at Mullica Hill, Timber Creek, New Egypt and several other localities.

NOTES ON ENCLOSING IN COLLODION SECTIONS OF OBJECTS EMBEDDED IN PARAFFIN, AND REGARDING PROVISORY OBJECT-SUPPORT.

BY LUDWIG RIEDERER.

(*Read December 6th*, 1889.)

When working with serial sections for the study of the cellular constitution of animal organs, or for the study of the relative position of the different organs in the body of an animal, the observer often secures a surprising number of sections, usually of large size. As it is possible to inspect these sections only after they are on the slide and finished, the amount of slides and cover-glasses employed, as well as that of time and labor expended is considerable. Consequently only one section out of a smaller or larger number is mounted. It takes some time to finish the slides for inspection, and then it may be found desirable to be able to inspect more of the sections of a certain part of the series.

How then is it possible to preserve and to keep in order the sections, so that, when needed, the desirable ones can be picked out and be found in good condition? It will not do to leave sections lying on the paper, where they are first deposited from the knife, even if they are so kept in a box. The slightest current of air will blow them away, and movement of the box will displace them. Besides this, sections not covered by a proper substance will deteriorate by exposure to the air. Many researches have been made, with more or less of success, to attain the desired end.

I wish to report to some extent the method worked out by Prof. H. Straper of Freiburg, Baden, Germany, and published in the last number of *Zeitschrift für Wissenschaftliche Mikroskopie*, Vol. VI. The article is entitled, "About the treatment of sections of objects embedded in paraffin." Three steps are observed in the method: First; enclosing sections in a film of collodion. Second; placing them on provisory supports. Third; handling the sections while enclosed in collodion, in case the object has not already been stained. It is about the first and second steps that I intend to speak, leaving the third for another time.

The consecutive steps here described are for objects already stained. For enclosing the sections in a film of collodion, there is needed, in the first place, a thin paper of even surface, and evenly saturated with the smallest sufficient quantity of wax or paraffin. This treatment will prevent the solution of collodion from entering the body of the paper. Two solutions of collodion of different composition are used. No. 1 consists of two parts of collodion and one part of castor-oil. No. 2 consists of equal parts of each, all by weight. By means of a large, soft brush a coat of collodion, No. 1, is spread upon the paraffin-paper. On this coat the sections, intended to be enclosed, are laid in order, where they receive a full coat of collodion, No. 2, the presence of air-bubbles being carefully avoided. Then, before bubbles of ether in the interior of the collodion may begin to form, the paper, carrying collodion and sections, is immediately immersed in a bath of spirit of turpentine. The spirit of turpentine hardens the collodion, by extracting the ether, alcohol and castor-oil contained in the solution. Slightly warming the bath quickens the process. The coating of collodion, after immersion in turpentine, first appears milky white, but presently it becomes transparent and colorless, and then the hardening is done.

Now the film of collodion lies isolated in the paper, out of which the paraffin or wax is dissolved by the turpentine. If, while laying the sections on the collodion, a small piece of paper, bearing the number of the adjoining section, is occasionally inserted, this also is enclosed in the film and helps to distinguish sections afterwards desired. The film being hardened and isolated, sections desired for permanent mounting and inspection can be easily selected. They are cut out by means of scissors or knife, and mounted in the regular way in balsam, noting the number or other mark of any section on the label of the slide.

The sections not selected for immediate permanent mounting must then be enclosed in rosin for preservation. To do this take the strips of paper, on which the collodion films rest, out of the turpentine bath ; let the oil drain off as much as possible; transfer them to filtering paper, and remove the surplus oil. The film containing the sections is then covered, by means of a soft brush, with a thick layer of a strong solution of light-colored

rosin in oil of turpentine. The oil of turpentine will be mostly absorbed by the film. Thin writing or tracing paper is then laid on the film, avoiding bubbles. On carefully raising this paper the film will adhere, and can be lifted off the paper it lay on first. A coat of the rosin is then applied to the lower side of the film, and the old paper, or tracing paper put over it. It is allowed to dry on the filtering paper. In case rosin should blot through the paper it is removed with turpentine. Remarks can be written on the covering paper, and the whole plate, or temporary support, is preserved in a portfolio between filtering paper, free from pressure and open to the access of air.

In holding such a plate against the light, it is possible to see at once the coarser items. For inspection under the microscope, the plate is put between a slide and cover-glass, adding oil, creosote, &c. to make the whole more transparent. Whenever then it is desirable to mount permanently single sections, or whole series of them, corresponding pieces of the provisory support are cut out and immersed in the turpentine bath. The rosin being dissolved, the film is separated from the covering paper, and can be mounted in the regular way. On the label of the slide can be marked the numbers, corresponding with the numbers embedded in the film with the sections. In this way it is possible to keep a large number of sections in good condition, easily distinguishable, and always ready for permanent mounting.

PROCEEDINGS.

Meeting of December 6th, 1889.

The Vice-President, Mr. P. H. Dudley, in the chair.

Thirty persons present.

The following Commitees were appointed by the chair:

On Annual Reception; Walter H. Mead, Charles S. Shultz, William Wales:

On Nominations of Officers; F. W. Devoe, F. W. Leggett, William G. De Witt.

Mr. L. Riederer read a Paper, entitled "Notes on enclosing in collodion sections of objects, embedded in paraffin, and regarding provisory support." This Paper Mr. Riederer illustrated

by a demonstration of the process before the Society, and it is published in this number of the JOURNAL, p. 56.

OBJECTS EXHIBITED.

1. A new ½ inch Powell and Lealand Objective : by ALBERT MANN, JR.

2. A "C" Eye-piece of Powell and Lealand, made from the "New Glass" : by WILLIAM G. DE WITT.

3. A "C" Eye-piece of Zentmayer : by WILLIAM G. DE WITT.

4. *Drosera rotundifolia*, with captive insect : by GEO. C. F. HAAS.

5. *Utricularia*, with captive insect : by GEO. C. F. HAAS.

6. Diatoms of the genus *Hyalodiscus :* by E. A. SCHULTZE.

7. Diatoms of the genus *Rhizosolenia :* by E. A. SCHULTZE.

8. Spherules from slag of blast-furnace, showing multiple images.

9. Spicules from disintegrated cherty strata ; polarized.

10. Quartz crystals from surface of iron ore (Hematite) ; polarized.

11. Section of fossil Coral ; polarized.

12. Diatoms from the lake, creek and springs of Birmingham, Alabama.

13. Selected Diatoms from the same.

Nos. 8–13, inclusive, were prepared by K. M. Cunningham, of Birmingham, Alabama, Corresponding Member of the Society, and were exhibited by J. L. ZABRISKIE.

The Corresponding Secretary read a communication from Mr. Cunningham, containing information on many points of interest in the slides prepared by him, and exhibited, as stated above, and donating to the Society the said slides, together with the following objects and material :

Natural plate of crystals from bituminous coal of Birmingham.

The same, uncovered, showing iridescence by slanting light.

Nodule of fossil coral from Birmingham.

A packet of joints of encrinite stems and crystals from weathered limestone of Birmingham.

Sand from disintegrated chert.

Hollow grains from weathered limestone.

Spherule dust from blast-furnace.

Nodule of chert with spicules.

Calcispheræ in fossiliferous limestone, polished on two sides, from Llangellen, Wales.

Microphotograph, containing forty-eight portraits.

In his communication, Mr. Cunningham stated, that the selected Diatoms—exhibit No. 13—were transferred directly from a strewn slide to the exhibiting slide by the aid of a "Kain's Mechanical Finger," attached to a Beck's ½ inch objective, the slide being manipulated by the left hand, and the bristle being directed into the field from the left-hand side. This method counteracts the effect of reversal of image, enabling every desired movement to be accomplished with ease and certainty. The right hand assists in racking the Diatom from the slide, high enough to clear the edge of the cover-glass, upon which the Diatoms are to be fixed. Very minute species are selected and isolated by this means. And further, that the specimen of fossiliferous limestone from Wales, showing a profusion of Polycystinous bodies—Calcispheræ—may be prized as a relic, from the fact that it was given by Mr. Shrubsole of Chester, England—who first described it to the microscopical world—to Dr. Stolterforth, the eminent diatomist of Chester, who, in turn, gave the rough specimen to Mr. Cunningham.

Meeting of December 20th, 1888.

The President, Mr. Charles F. Cox, in the chair.

Twenty-seven persons present.

The Corresponding Secretary read a communication from the Hon. Marshall D. Ewell, LL.D., Corresponding Member of the Society, entitled "Amplification in Micrometry." This communication is published in this volume of the Journal, p. 4.

Mr. Anthony Woodward read, by title, a Paper, entitled "Synopsis of the cretaceous Foraminifera of New Jersey. Part 1. Review of previous investigations." This Paper is published in this number of the Journal, p. 45.

Objects exhibited.

1. Diatoms from Storen, containing *Suriella spiralis:* by Charles S. Shultz.

2. The Diatom, *Cymatopleura nobilis:* by Charles S. Shultz.

3. The Diatom, *Rhaphidodiscus Febigerii:* by Geo. C. F. Haas.

4. Scales of 30 varieties of South American Lepidoptera: by Thomas B. Briggs.

5. Monazite sand from Brazil: by Thomas B. Briggs.

6. Section of Hydro-magnesite, showing radiating crystallization, from Hoboken, N. J.: by James Walker.

7. Radiating crystals of Hydro-magnesite from Hoboken, N. J.: by Geo. E. Ashby.

8. Section of silicious Geode from the sub-carboniferous shales of Warsaw, Illinois: by J. D. Hyatt.

9. Section of silicious fossil Coral, *Favosites:* by J. D. Hyatt.

10. *Actinophrys sol:* by Stephen Helm, of 417 Putnam avenue, Brooklyn, N. Y.

Mr. Hyatt described his exhibits with the employment of black-board sketches, and stated that the geodes from Warsaw are of all sizes, from one-half of an inch to a foot or more in diameter, and, when broken, they are generally found to be hollow, with the cavity lined with crystals of calcite or quartz. As the formation in which they occur, is entirely calcareous it is not a little interesting to observe, as in this section, the complete molecular change which some of them have undergone. The side of the section representing the exterior is chalcedonic, for the depth of about one-eighth of an inch, showing the radiating fibrous structure and peculiar polarization of that mineral. The interior wall is compact crystalline quartz.

The section of *Favosites* is also completely metamorphosed. The cell-walls of the coral and the structure for a short distance inward are chalcedony, while the interior of each cell is entirely filled with microscopic quartz crystals.

Mr. Helm described his exhibit, and also reported, that on a late occasion he kept a female *Daphnia* in a minute drop of water in a live-box over night, and that on the next morning—after an interval of about eleven hours—he found her still living, and having produced fourteen living young, "all the very image of their mother."

Meeting of January 3d. 1890.

The President, Mr. Charles F. Cox, in the chair.

Twenty-nine persons present.

Miss Mary A. Booth, of Longmeadow, Mass., was elected a Corresponding Member of the Society.

The Committee on Nominations of Officers, appointed at the meeting of December 6th, 1889, reported their nominations of the persons who were unanimously elected, as is stated below:

The President appointed as Tellers of the election of Officers Mr. H. W. Calef, and the Rev. Geo. C. F. Haas.

The annual Reports of the Treasurer and of the Committee on Publications were presented and adopted.

The President, Mr. Charles S. Cox, delivered his Annual Address, entitled "Protoplasm and the Cell Doctrine." This Address is published in this number of the JOURNAL, p. 17.

OBJECTS EXHIBITED.

1. The Diatom, *Rhaphidodiscus Febigerii*, Smith: by E. A. SCHULTZE.

2. Alimentary tube of the Blue-bottle Fly, *Musca* (*Lucilia*) *Cæsar*, L., exhibited in its entire length from œsophagus to rectum, with some of the neighboring organs, as glands, malpighian vessels, tracheæ and ovarian tubes containing eggs: by L. RIEDERER.

The President announced the closing of the polls, and declared the result of the balloting to be the election of the following persons as Officers of the Society for the present year:

President, P. H. DUDLEY.
Vice-President, J. D. HYATT.
Recording Secretary, BASHFORD DEAN.
Corresponding Secretary, J. L. ZABRISKIE.
Treasurer, CHARLES S. SHULTZ.
Librarian, LUDWIG RIEDERER.
Curator, WILLIAM BEUTTENMÜLLER.
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MEETING OF JANUARY 17TH, 1890.

The President, Mr. P. H. Dudley, in the chair.

Twenty-five persons present.

The President delivered his Inaugural Address.

Mr. Alfred L. Beebee, was elected a Resident Member of the Society.

Mr. Charles F. Cox gave notice of a proposed amendment of Article X of the By-Laws of the Society, striking out the words "roll-call," wherever they occur in said Article.

On motion, the resignation of the members of the Committee on Annual Reception, because of their inability to devote their time to the labor necessarily required from such Committee, was accepted.

The President appointed the following persons as Committee on Annual Reception: Charles F. Cox, Anthony Woodward, James Walker.

The following were appointed as a Committe to procure six objectives, of moderate power and cost, for the use of the Society: J. D. Hyatt, J. L. Zabriskie and William G. De Witt.

The following were appointed as the Committee on Publications: J. L. Zabriskie, William G. De Witt, Walter H. Mead, John L. Wall and George E. Ashbey.

OBJECTS EXHIBITED.

1. Sections of Basalt, containing native iron, from Ovifak, Greenland: by JAMES WALKER.

2. The fungus, *Sporocybe cellare*, Peck, new species, showing capitulum and spores: by J. L. ZABRISKIE.

3. Spiral tracheids of Yellow Pine, *Pinus palustris*, Mill.: by P. H. DUDLEY.

4. Spiral tracheids of White Cedar, *Chamæcyparis sphæroidea*, Spach: by P. H. DUDLEY.

Slides of diatomaceous deposits from the Yellowstone Geyser region: by C. HENRY KAIN;

5. Deposit from the Yellowstone Lake.
6. Deposit from Norris's Meadow.
7. Deposit from Geyser Meadow.
8. Deposit from Nez Perces Creek.
9. Deposit (amorphous silica) from Sulphur Hill.

Mr. Dudley read a Paper describing his exhibits.

Mr. Kain stated concerning his exhibits, that this material from the Yellowstone Geyser region was presented to him by Mr. Walter Harvey Weed, of the U. S. Geological Survey. The diatoms contained are ordinary fresh-water forms, but there are

some points of more than ordinary interest connected with them.

Mr. Weed has described—Botanical Gazette, xiv, 117—the vast diatom-marshes of the Yellowstone National Park, which owe their origin to the fact that the water from the geysers is highly charged with silica.

The crude material appears to be composed of vast numbers of diatoms, associated with the dried gelatinous matter, which usually accompanies such deposits. The usual methods of cleaning the diatoms by boiling in the mineral acids, however, almost entirely fail with these deposits, for the reason that what appears at first to be only the usual accompanying organic matter is in reality silicious sinter. An attempt to get rid of this by boiling the deposit in caustic potash resulted in the destruction of the diatomaceous frustules, while the sinter itself was scarcely attacked.

The deposits are quite similar in regard to the character of the species found, the largest forms, however, occurring in the cooler waters of the Yellowstone Lake.

This subject was discussed by Mr. E. A. Schultze and Dr. N. L. Britton.

Mr. Kain donated the five slides of his exhibit to the Cabinet of the Society.

PUBLICATIONS RECEIVED.

The Microscope: Vol. IX., Nos. 10, 12—Vol. X., No. 2 (December, 1889, February, 1890).

The American Monthly Microscopical Journal: Vol. X., Nos. 10, 12—Vol. XI., Nos. 1, 2 (October, 1889—February, 1890).

The Microscopical Bulletin and Science News: Vol. VI., No. 6 (December, 1889).

Anthony's Photographic Bulletin: Vol. XX., No. 23—Vol. XXI., No. 5 (December 14, 1889—March 8, 1890).

Entomologica Americana: Vol. V., No. 10—Vol. VI., No. 3 (October, 1889—March, 1890).

Psyche: Vol. V., Nos. 160-166 (August, 1889-February, 1890).

Insect Life: Vol. II., Nos. 5-8 (November, 1889-February, 1890).

Bulletin of the Torrey Botanical Club: Vol. XVI., No. 12—Vol. XVII., No. 2 (December, 1889-February, 1890).

The Botanical Gazette: Vol. XIV., No. 12—Vol. XV., No. 1 (December, 1889-January, 1890.)

The School of Mines Quarterly: Vol. XI., Nos. 1, 2 (November, 1889–January, 1890).

San Francisco Microscopical Society, Proceedings (December 11, 1889).

Natural Science Association of Staten Island, Proceedings (December 12, 1889–February 13, 1890).

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American Academy of Arts and Sciences, Boston; Proceedings: Vol. XXIII., Part 2 (1888).

The West American Scientist: Vol. VI., No. 49 (November, 1889).

Kansas Academy of Science, Transactions (1887-88).

Washburn College Laboratory, Bulletin: Vol. II., No. 10 (December, 1889).

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The Satellite: Vol. III., Nos 4–6 (December, 1889–February, 1890).

The Hahnemannian Monthly: Vol. XXIV., No. 12—Vol. XXV., No. 3 (December, 1889–March, 1890).

The Medical Analectic and Epitome: Vol. VI., No. 49—Vol. VII., No. 1 (December 5, 1889–January, 1890).

Indiana Medical Journal: Vol. VIII., Nos. 6–8 (December, 1889–February, 1890).

The Electrical Engineer: Vol. IX., Nos. 97, 98 (January, February, 1890).

The American Lancet: Vol. XIII., No. 12—Vol. XIV., No. 2 (December, 1889–Februray, 1890).

The Pacific Record of Medicine and Surgery: Vol. IV., Nos. 5–7 (December, 1889–February, 1890).

National Druggist: Vol. XV., No. 12—Vol. XVI., No. 5 (December 15, 1889–March 1, 1890).

Mining and Scientific Review: Vol. XXIII., No. 21—Vol. XXIV., No. 9 (December 5, 1889–February 27, 1890).

The Canadian Record of Science: Vol. III., No. 8—Vol. IV., No. 1 (October, 1889–January, 1890).

Nova Scotian Institute of Natural Science, Proceedings: Vol. VI., Part 2—Vol. VII., Part 3 (1883–89).

The Ottawa Naturalist: Vol. III., No. 3 (October, 1889).

The Canadian Institute: Proceedings, Vol. VII., No. 1 (October, 1889); Annual Report (1889).

Natural History in Elementary Schools; by H. Hensoldt, Ph. D. (1890).

A Naturalist's Rambles in Ceylon; by H. Hensoldt, Ph. D. (1889).

The New York Free Circulating Library, Annual Report (1889).

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The Victorian Naturalist: Vol. VI., Nos. 7–9 (November, 1889–January, 1890).

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Naturforschende Gesellschaft zu Freiburg, Berichte: Vol. III.—Vol. IV., No. 5 (1888, 1889).

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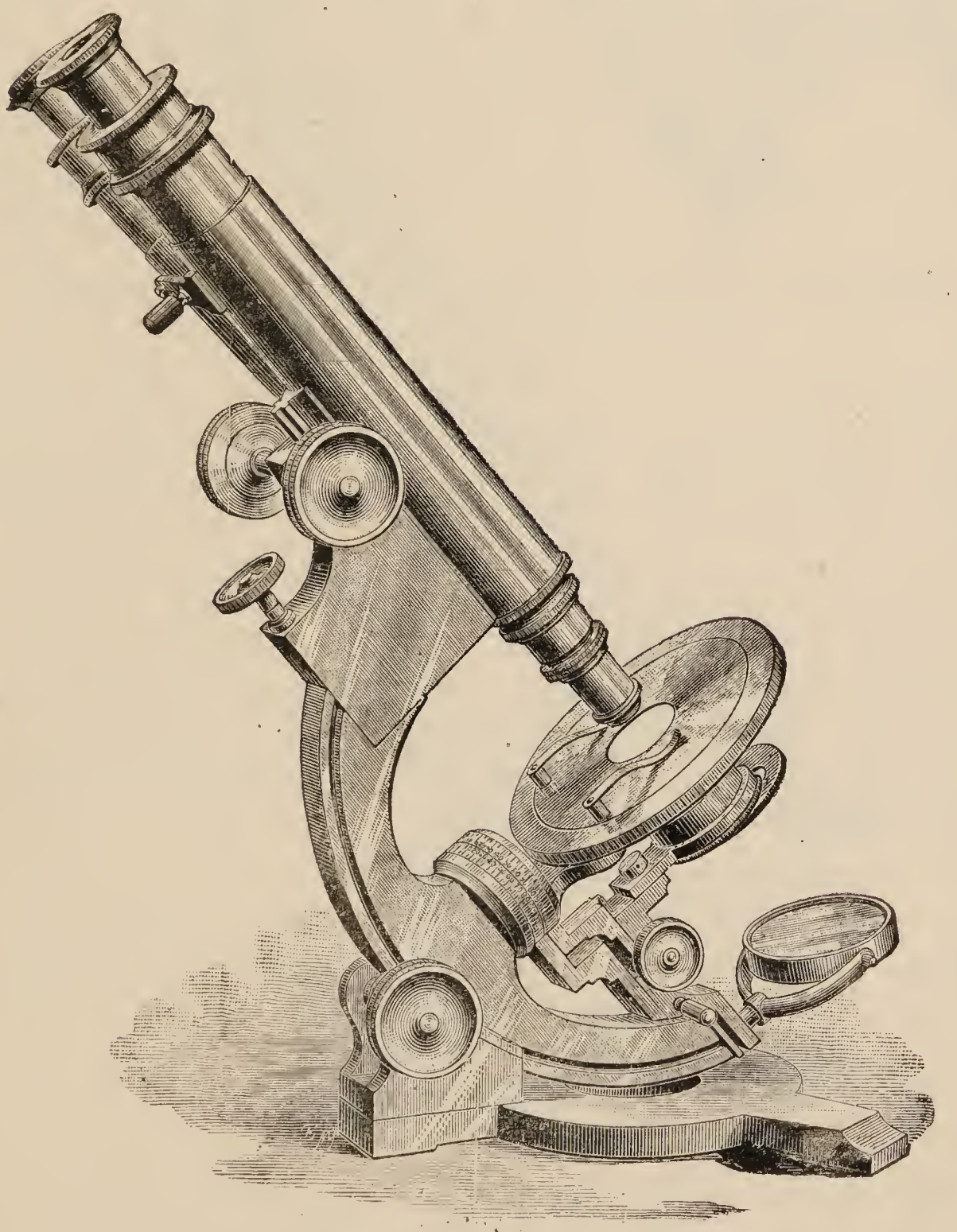

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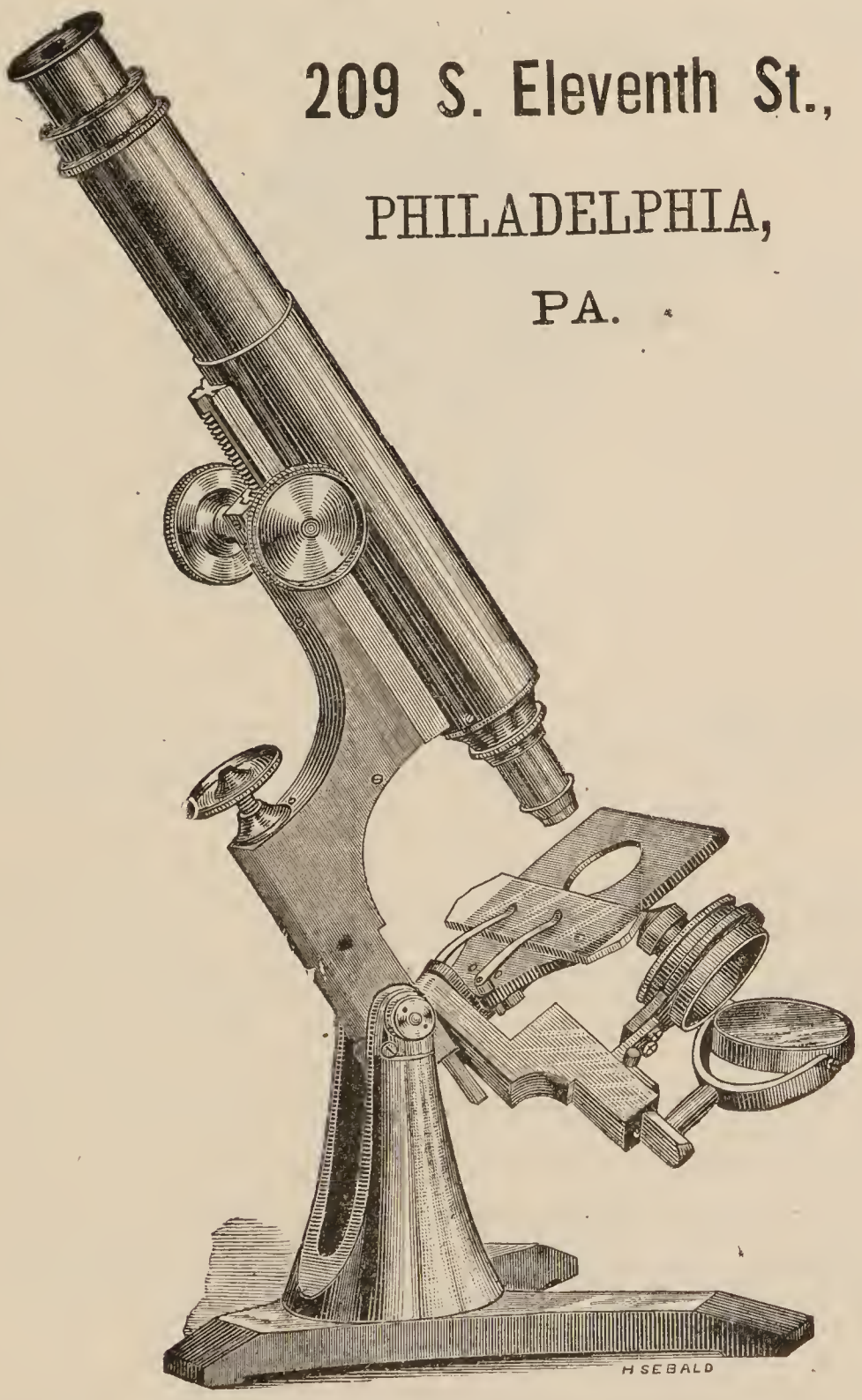

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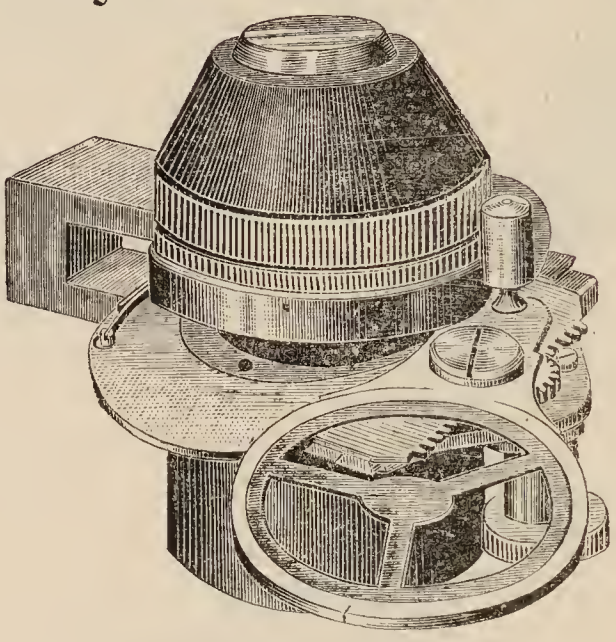

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This ratio is expressed for all media and in all cases by $n \sin u$, n being the refractive index of the medium and u the semi-angle of aperture. The value of $n \sin u$ for any particular case is the "*numerical aperture*" of the objective.

Numerical Aperture. ($n \sin u = a$.)	Angle of Aperture ($= 2u$.)			Illuminating Power. (a^2.)	Theoretical Resolving Power, in Lines to an Inch. ($\lambda = 0{\cdot}5269\,\mu$ = line E.)	Penetrating Power. $\left(\frac{1}{a}\right)$
	Dry Objectives. ($n = 1$.)	*Water-Immersion* Objectives. ($n = 1{\cdot}33$.)	*Homogeneous-Immersion* Objectives. ($n = 1{\cdot}52$.)			
1·52	..	..	180° 0′	2·310	146,528	·658
1·50	..	..	161° 23′	2·250	144,600	·667
1·48	..	..	153° 39′	2·190	142,672	·676
1·46	..	..	147° 42′	2·132	140,744	·685
1·44	..	..	142° 40′	2·074	138,816	·694
1·42	..	..	138° 12′	2·016	136,888	·704
1·40	..	..	134° 10′	1·960	134,960	·714
1·38	..	..	130° 2′	1·904	133,032	·725
1·36	..	..	126° 57′	1·850	131,104	·735
1·34	..	..	123° 40′	1·796	129,176	·746
1·33	..	180° 0′	122° 6′	1·770	128,212	·752
1·32	..	165° 56′	120° 33′	1·742	127,248	·758
1·30	..	155° 38′	117° 34′	1·690	125,320	·769
1·28	..	148° 28′	114° 44′	1·638	123,392	·781
1·26	..	142° 39′	111° 59′	1·588	121,464	·794
1·24	..	137° 36′	109° 20′	1·538	119,536	·806
1·22	..	133° 4′	106° 45′	1·488	117,608	·820
1·20	..	128° 55′	104° 15′	1·440	115,680	·833
1·18	..	125° 3′	101° 50′	1·392	113,752	·847
1·16	..	121° 26′	99° 29′	1·346	111,824	·862
1·14	..	118° 0′	97° 11′	1·300	109,896	·877
1·12	..	114° 44′	94° 56′	1·254	107,968	·893
1·10	..	111° 36′	92° 43′	1·210	106,040	·909
1·08	..	108° 36′	90° 33′	1·166	104,112	·926
1·06	..	105° 42′	88° 26′	1·124	102,184	·943
1·04	..	102° 53′	86° 21′	1·082	100,256	·962
1·02	..	100° 10′	84° 18′	1·040	98,328	·980
1·00	180° 0′	97° 31′	82° 17′	1·000	96,400	1·000
0·98	157° 2′	94° 56′	80° 17′	·960	94,472	1·020
0·96	147° 29′	92° 24′	78° 20′	·922	92,544	1·042
0·94	140° 6′	89° 56′	76° 24′	·884	90,616	1·064
0·92	133° 51′	87° 32′	74° 30′	·846	88,688	1·087
0·90	128° 19′	85° 10′	72° 36′	·810	86,760	1·111
0·88	123° 17′	82° 51′	70° 44′	·774	84,832	1·136
0·86	118° 38′	80° 34′	68° 54′	·740	82,904	1·163
0·84	114° 17′	78° 20′	67° 6′	·706	80,976	1·190
0·82	110° 10′	76° 8′	65° 18′	·672	79,048	1·220
0·80	106° 16′	73° 58′	63° 31′	·640	77,120	1 250
0·78	102° 31′	71° 49′	61° 45′	·608	75,192	1·282
0·76	98° 56′	69° 42′	60° 0′	·578	73,264	1·316
0·74	95° 28′	67° 36′	58° 16′	·548	71,336	1·351
0·72	92° 6′	65° 32′	56° 32′	·518	69,408	1·389
0·70	88° 51′	63° 31′	54° 50′	·490	67,480	1·429
0·68	85° 41′	61° 30′	53° 9′	·462	65,552	1·471
0·66	82° 36′	59° 30′	51° 28′	·436	63,624	1·515
0·64	79° 35′	57° 31′	49° 48′	·410	61,696	1·562
0·62	76° 38′	55° 34′	48° 9′	·384	59,768	1·613
0·60	73° 44′	53° 38′	46° 30′	·360	57,840	1·667
0·58	70° 54′	51° 42′	44° 51′	·336	55,912	1·724
0·56	68° 6′	49° 48′	43° 14′	·314	53,984	1·786
0·54	65° 22′	47° 54′	41° 37′	·292	52,056	1·852
0·52	62° 40′	46° 2′	40° 0′	·270	50,128	1·923
0·50	60° 0′	44° 10′	38° 24′	·250	48,200	2·000

EXAMPLE.—The apertures of four objectives, two of which are dry, one water-immersion, and one oil-immersion, would be compared on the *angular* aperture view as follows:—106° (air), 15[illegible] (air), 142° (water), 130° (oil).

Their actual apertures are, however, as ·80 (air), ·98 (air), 1·26 (water), 1·38 (oil), or their numerical apertures.

* From The Journal of the Royal Microscopical Society.

II. Conversion of British and Metric Measures.

(1.) Lineal.

Micromillimetres, &c., into Inches, &c.

μ	ins.
1	·000039
2	·000079
3	·000118
4	·000157
5	·000197
6	·000236
7	·000276
8	·000315
9	·000354
10	·000394
11	·000433
12	·000472
13	·000512
14	·000551
15	·000591
16	·000630
17	·000669
18	·000709
19	·000748
20	·000787
21	·000827
22	·000866
23	·000906
24	·000945
25	·000984
26	·001024
27	·001063
28	·001102
29	·001142
30	·001181
31	·001220
32	·001260
33	·001299
34	·001339
35	·001378
36	·001417
37	·001457
38	·001496
39	·001535
40	·001575
41	·001614
42	·001654
43	·001693
44	·001732
45	·001772
46	·001811
47	·001850
48	·001890
49	·001929
50	·001969
60	·002362
70	·002756
80	·003150
90	·003543
100	·003937
200	·007874
300	·011811
400	·015748
500	·019685
600	·023622
700	·027559
800	·031496
900	·035433
1000	(= 1 mm.)

mm.		ins.
1		·039370
2		·078741
3		·118111
4		·157482
5		·196852
6		·236223
7		·275593
8		·314963
9		·354334
10	(1 cm).	·393704
11		·433075
12		·472445
13		·511816
14		·551186
15		·590556
16		·629927
17		·669297
18		·708668
19		·748038
20	(2 cm.)	·787409
21		·826779
22		·866150
23		·905520
24		·944890
25		·984261
26		1·023631
27		1·063002
28		1·102372
29		1·141743
30	(3 cm.)	1·181113
31		1·220483
32		1·259854
33		1·299224
34		1·338595
35		1·377965
36		1·417336
37		1·456706
38		1·496076
39		1·535447
40	(4 cm.)	1·574817
41		1·614188
42		1·653558
43		1·692929
44		1·732299
45		1·771669
46		1·811040
47		1·850410
48		1·889781
49		1·929151
50	(5 cm.)	1·968522

mm.		ins.
51		2·007892
52		2·047262
53		2·086633
54		2·126003
55		2·165374
56		2·204744
57		2·244115
58		2·283485
59		2·322855
60	(6 cm.	2·362226
61		2·401596
62		2·440967
63		2·480337
64		2·519708
65		2·559078
66		2·598449
67		2·637819
68		2·677189
69		2·716560
70	(7 cm.)	2·755930
71		2.795301
72		2·834671
73		2·874042
74		2·913412
75		2·952782
76		2.992153
77		3 031523
78		3·070894
79		3·110264
80	(8 cm.)	3·149635
81		3·189005
82		3·228375
83		3·267746
84		3·307116
85		3·346487
86		3·385857
87		3·425228
88		3·464598
89		3·503968
90	(9 cm.)	3·543339
91		3·582709
92		3·622080
93		3·661450
94		3·700820
95		3·740191
96		3·779561
97		3·818932
98		3·858302
99		3·897673
100	(10 cm. = 1 decim.)	

decim.		ins.
1		3·937043
2		7·874086
3		11·811130
4		15·748173
5		19·685216
6		23·622259
7		27·559302
8		31·496346
9		35·433389
10	(1 metre)	39·370432

= 3·280869 ft.

= 1·093623 yds.

Inches, &c., into Micromillimetres, &c.

ins.	μ
$\frac{1}{25000}$	1·015991
$\frac{1}{20000}$	1·269989
$\frac{1}{15000}$	1·693318
$\frac{1}{10000}$	2·539977
$\frac{1}{9000}$	2·822197
$\frac{1}{8000}$	3·174972
$\frac{1}{7000}$	3·628539
$\frac{1}{6000}$	4·233295
$\frac{1}{5000}$	5·079954
$\frac{1}{4000}$	6·349943
$\frac{1}{3000}$	8·466591
$\frac{1}{2000}$	12·699886
$\frac{1}{1000}$	25·399772

	mm.
$\frac{1}{900}$	·028222
$\frac{1}{800}$	·031750
$\frac{1}{700}$	·036285
$\frac{1}{600}$	·042333
$\frac{1}{500}$	·050800
$\frac{1}{450}$	·056444
$\frac{1}{400}$	·063499
$\frac{1}{350}$	·072571
$\frac{1}{300}$	·084666
$\frac{1}{250}$	·101599
$\frac{1}{200}$	·126909
$\frac{1}{150}$	·169332
$\frac{1}{100}$	·253998
$\frac{1}{50}$	·507995
$\frac{1}{25}$	1·015991
$\frac{1}{20}$	1·269989
$\frac{1}{16}$	1·587486
$\frac{1}{15}$	1·693318
$\frac{1}{12}$	2·116648
$\frac{1}{10}$	2·539977
$\frac{1}{8}$	3·174972
$\frac{1}{6}$	4·233295
$\frac{3}{16}$	4·762457
$\frac{1}{5}$	5·079954
$\frac{1}{4}$	6·349943
$\frac{5}{16}$	7·937429
$\frac{3}{8}$	9·524915

	cm.
$\frac{7}{16}$	1·111240
$\frac{1}{2}$	1·269989
$\frac{9}{16}$	1·428737
$\frac{5}{8}$	2·587486
$\frac{11}{16}$	1·746234
$\frac{3}{4}$	1·904983
$\frac{13}{16}$	2·063732
$\frac{7}{8}$	2·222480
$\frac{15}{16}$	2·381229
1	2·539977
2	5·079954
3	7·619932

	decim.
4	1·015991
5	1·269989
6	1·523986
7	1·777984
8	2·031982
9	2·285979
10	2·539977
11	2·793975
1 ft.	3·047973

	metres.
1 yd. =	·914392

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